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THE FRANKLIN INSTITUTE.

Stated Meeting, held Wednesday, September 16, 1896.

MR. JOS. M. WILSON, President, in the chair.

WORK OF THE COMMITTEE ON FIRE-PROOFING TESTS.

BY S. ALBERT REED, PH.D.

The Term "Fire-Proof."—Fire underwriters use the term fire-proof generically, denoting a class of construction in which no structural member is combustible, with full appreciation of the fact, however, that fire may cause complete wreck without actual combustion of the structure. Some of those practically interested have undertaken to investigate the causes and nature of damage from fire to this class of structure. A co-operative committee of three was formed nearly a year ago, representing officially the principal associations of Fire Insurance Underwriters, the Architectural League and the American Society of Mechanical

Engineers. This committee has done little more, so far, than to construct its plant and to make a beginning of its tests. The results, so far, are, however, for interest and importance, a justification of its expectations.

Growth of Fire-Proof Construction.—With regard to the modern fire-proof building, the situation must be accepted as we find it. It is futile to argue whether or not we should approve of the erection of 25-story steel cages without sustaining walls. Such structures are already thronging our cities and, although we may eventually regulate and restrain many of their eccentricities, we must adapt ourselves to them. Moreover we shall doubtless witness within a generation the transformation of our construction very extensively in this direction.

Only ten years ago there were comparatively few of the fire-proof type in the United States, and these were mainly office buildings or public buildings. In the great Chicago fire there were but three of this type (see *Plate 1*); in the Boston fire none. I do not refer to newspaper reporters' fire-proof buildings, but to fire underwriters' fire-proof buildings. To-day we have over 500 in New York and over 200 now going up. In Chicago there is a large number, and in Philadelphia and Boston and elsewhere the style is rapidly becoming familiar. In England and on the European Continent the type has long been general for mills and factories. In Paris, in 1892, I found no buildings, not even dwellings, being erected other than fire-proof, and fire-proof also with a good protection of structural metal.

Fire Classification of Construction.—Fire underwriters consider three types of buildings:

(1) Ordinary construction.

(2) Slow-burning construction.

(3) Fire-proof construction.

Inasmuch as all three may have brick exterior walls, elevators and stairways in brick enclosures, and no hollow or combustible finish, the distinction does not depend upon those elements, but is found in the floor and column construction.

In the slow-burning type the aim is either, as in the mill

type, by massiveness and avoidance of excessive wood surface, to produce a building which will retain structural integrity even after a quite extensive burning, or as in the protected wooden beam type, the aim is to armor the structural wood against ignition and combustion.

In both of the slow-burning types an essential to the fulfilment of the purpose is that human or mechanical aid shall be competent, if allowed sufficient time, to extinguish the fire. In the fire-proof type, the reliance is on passive brute resistance to survive a fire without structural impairment in spite of a possible complete failure of human aid, which failure may be due to repulse on account of heat, smoke or breakdown, or on account of inaccessibility to the work of fire-apparatus due to great area or great height. The case is similar to that of the fast unarmored cruiser compared with the heavily armored battleship, the one relying for defence upon human activity and courage, and the other upon brute passive resistance to any injury which may be vital, while admitting the probability of very great injury short of vital. For many purposes the second type of construction may be satisfactory or even better than the third, but in a conflagration, as in a pitched naval battle, any type other than the third would be hopelessly outclassed.

Essentials of a Fire-Proof Building.—In modern fire-proof construction, the bold stroke of abolishing the exterior wall as a sustaining member, and relegating it to the function of a screen, was really only a climax of the inevitable, and a frank recognition of the fact that already the sustaining feature was, in large buildings, practically only a formal survival of the organ of an extinct function, like the tail buttons of a man's coat. The old-time warehouse was ordinarily 20 to 25 feet wide, the beams spanned the entire width and were carried by the side walls, while the front and rear walls were not bearing walls. In a modern large building, say 150 x 100 feet, the floors are twelve-thirteenths supported by the columns and one-thirteenth supported by the walls. Furthermore, if the walls are full of windows on all sides, it is merely the piers between the windows which are carriers of weight. In short, a large

building consists, structurally, essentially of its floors and roof and columns; the exterior walls, like the partitions, are screens or fire-stops. Furthermore, when we pass a height of 4 stories, few walls have any stability apart from the guying and bracing effect of the interior.

In a large building of ordinary construction, with brick walls, the term "brick building" is a misnomer. If the building is 6 stories high and 100 x 150 feet, the structural material figures as follows:

	Per Cent.
Brick walls, cubic feet	50
Lumber in floors and columns (about 500,000 lumber feet)	50

In an old-time building, 25 x 60, 4 stories high, the term brick building was more appropriate, as the proportion is:

	Per Cent.
Brick walls	75
Lumber	25

It was, thus, an easy step to abandon the exterior wall as an essential structural member. Therefore, while I would not underestimate the importance of constructing exterior walls so that they shall be efficient screens against external fires, yet it is a fact that, structurally, a modern fire-proof building consists primarily of its steel or iron skeleton and its floor and roof arches.

Duty of a Fire-Proof Building.—Finish or trim is usually more or less of combustible material, and is not expected to survive a fire; but a fire-proof building does not fulfil the duty proper to its type unless, for the fire ordeal which it is likely to be called upon to sustain, its skeleton shall be able to emerge from that ordeal with its structural integrity unimpaired, its floor and roof arches damaged only superficially or locally, if at all, and with its exterior walls, if not perforated by windows, having successfully excluded any external fire.

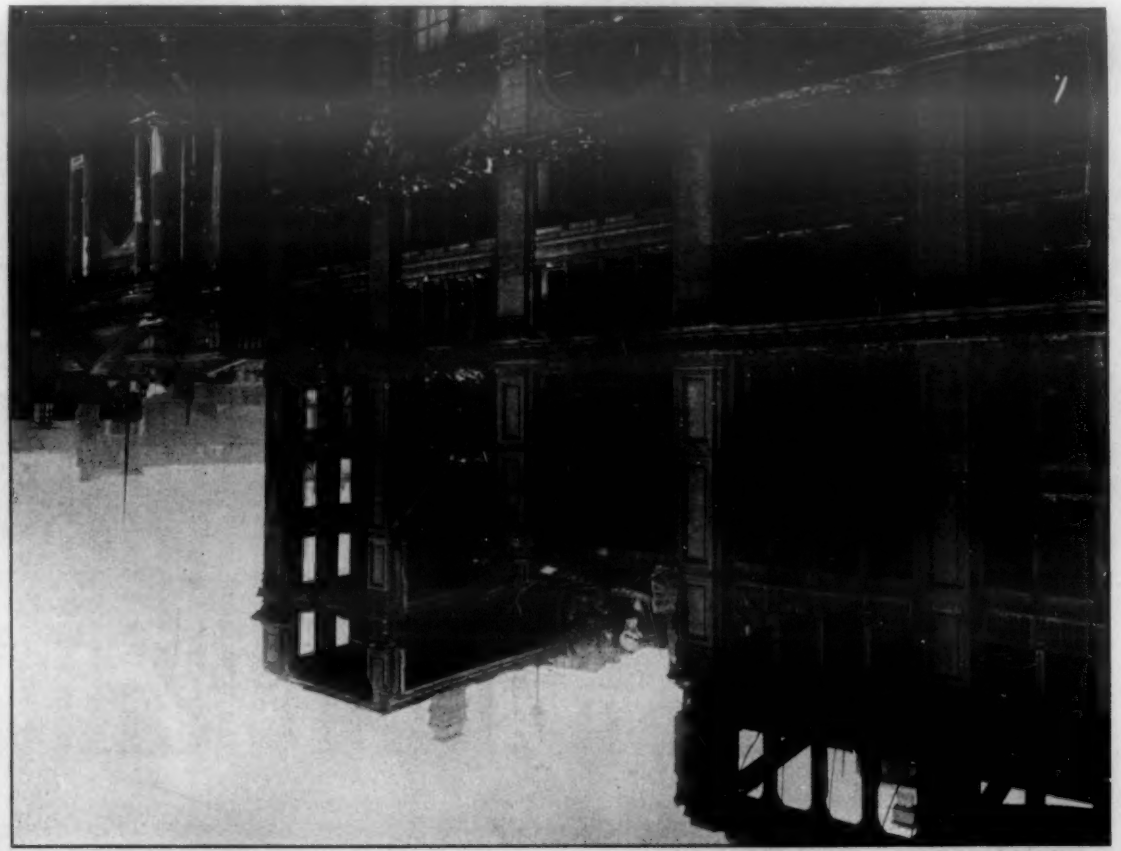
As regards the contents, if the fire is an external one, and has attacked the fire-proof building on a side full of windows without fire-shutters, we must anticipate a possible total destruction of contents. If the fire is an internal one, we may, provided we have cut off all vertical passages com-

PLATE I.—Building N. E. corner Monroe and LaSalle Streets, Chicago. View taken immediately after the great Chicago fire. The building was structurally unimpaired.

with unprotected steel girders, Bleecker Street and Broadway, New York.

PLATE 1.—Building N. E. corner Monroe and LaSalle Streets, Chicago. View taken immediately after the great Chicago fire. The building was structurally unimpaired.

PLATE 2.—Effect of heat from a fire across the street acting through the windows upon a building with unprotected steel girders, Bleecker Street and Broadway, New York.



pletely, anticipate a confinement of fire mainly to the floor where the fire has originated. But, in any case, even where fire has extended throughout the building, and all contents, together with finish, trim and mechanical plant and exterior wall ornamentation, are destroyed or wrecked, we must, in our ideal building, demand that it shall emerge from the ordeal unimpaired as to skeleton, and mainly unimpaired as to floor arches.

Relative Importance of Features.—Our investigation then will examine, in order of importance, how fire affects—

(1) The skeleton.

(2) The floor and roof arches.

(3) Walls and partitions regarded as fire-stops.

Fire underwriters will lay the most stress upon the protection of the skeleton, inasmuch as even a local damage may, by throwing the building out of line or plumb, or by dropping out the floor arches, involve the insurer in a total loss, due to the possibility that total demolition may be demanded by building laws, whereas the building may lose a very considerable section of the floor arches without such consequence.

Determination of the Plan of the Tests.—The varieties of fire-proof construction have reference mainly to the various devices for floor arches spanning the space between the steel beams, and such are largely the subject of patent rights. Quite a number of fire and water tests, mainly proprietary, have been made and are being made on floor arches, and those persons interested have already provided quite a fund of data on that subject. But investigation of the protection of the skeleton has not called forth the activity of patentees, and the heavy expense necessary has prevented others interested in ascertaining the facts from going thoroughly into the subject, until we took it up. I will partly except the Hamburg tests, which I will quote later. We determined that our test of the steel skeleton, namely of steel or iron columns, girders and beams, must be made on a full working scale and under the actual conditions, as far as possible, which would obtain in a fire. The only open questions were what fuel to use in generating

heat, at what temperature to work, and what time to require for each ordeal. We decided to use gas for fuel, to work at three typical temperatures, these to represent three typical classes of ordeal that buildings are likely to be called upon to sustain according to their location and occupancy, and to test each case to destruction if possible.

Typical Temperatures.—(1) Say 2,500° F., six hours. A conflagration ordeal for any building, or an occupancy ordeal for a building full of a stock of goods, such as furniture, for example.

(2) Say 1,200° F., one hour. An ordeal for a building subject to possibilities of mild external fire, or to the internal risk of moderate aggregations of combustible material, such as ordinary merchandise.

(3) Say 700° F., one-half hour, representing very mild conditions, such as would occur in an office building or dwelling in an office building or dwelling neighborhood.

It was debated whether the combustion of gas represented actual practical conditions, and whether wood fuel would not more nearly represent those conditions. It was decided to use gas on the following grounds:

(1) The damage to skeleton and floors, which is likely to affect their structural integrity, is almost entirely a matter of temperature, and 1,000° F. of heat is 1,000° F. of heat, no matter from what kind of fuel it is obtained, provided it is applied uniformly.

(2) To undertake the imitation of actual practical conditions would mean to go through the entire list of combustible merchandise—dry-goods, groceries, furniture, clothing, etc.—plainly an absurdity; whereas, having once recorded our test temperatures accurately, it is open for an independent series of tests to ascertain what temperature and heat units the combustion of any desired kind or quantity of merchandise will develop.

(3) It is so essential that, in successive tests, as nearly as possible uniform conditions should exist, that we must positively have a perfectly controllable source of heat, and gas is eminently such a source. I will add that the advice of Professor Morton, of Stevens Institute, concurred with this decision.

PLATE 3.—Effect of heat from a fire across the street acting through the windows upon a building with unprotected steel girders, Bleecker Street and Broadway, New York.

PLATE 4.—Looking North from Fifty-eighth Street.

PLATE 5.—The same, from another point of view.

Great fire of April, 1889, at Fifty-ninth Street and Eleventh Avenue, New York.

PLATE 3.—Effect of heat from a fire across the street acting through the windows upon a building with unprotected steel

Program to Include Test of Extreme Conditions.—Considering the plan of operation, it is necessary to bear in mind:

(1) That these tests were to be primarily aimed at obtaining data for standard specifications, and, as such, should not be allowed to degenerate into merely patentees' competitions. We decided, therefore, not to finance the undertaking by certificate fees from material men, but entirely by voluntary subscriptions from those interested with the users and not with the producers of fire-proof buildings. From the data we hope to obtain we shall be able to state the requirements for a standard building, for the particular set of conditions, internal and external, which the building is to meet. To be a standard it must contemplate all fire possibilities, even the most remote, pertaining to those conditions. This is not demanded in ordinary construction, but it is in fire-proof construction. It is not intended to advocate a prohibition of fire-proof buildings short of standard, but to establish a standard as a datum level from which allowable variations may be determined. A building which is placed in a conflagration district must, if standard, be prepared for the temperature and the duration of conflagration, and prepared to emerge therefrom structurally unimpaired. Such a survival of a conflagration, even with a damage of 75 per cent. of value, would be a matter of great importance to both owner and underwriter.

Conflagration Conditions.—A conflagration is attended with defeat of efforts at extinguishment, withdrawal of fire department, and abandonment of the field. No building will then survive except such as can offer successful passive resistance to very extreme temperatures sustained over unusual length of time. The surprising phenomena witnessed in large conflagrations, phenomena which are apt to draw out all sorts of fanciful theories to account for them, can all be accounted for if we admit the existence of extraordinary temperatures. Extraordinary temperatures are best obtained for experiment by a judiciously applied blast of air, the air being previously heated to a quite high temperature. Temperatures over 2,500° F. are thus easily obtained. Bunsen obtained a temperature of 3,600° F. with hydrogen and

air, and 5,150° F. with hydrogen and oxygen. In a conflagration the powerful currents of air generated have an opportunity, by passing over highly heated objects, to attain the effect of a genuine hot blast, such as is familiar in metallurgy. Then the effects of heat radiation are exhibited in conflagrations on an entirely unfamiliar scale. Radiation is a much underestimated factor. It can be easily calculated that a sheet of flame 60 x 60 at 2,500° will heat a point 60 feet away to the point of ignition of wood. It must also be borne in mind that radiation is independent of the direction of the wind. Furthermore, intensely heated air, even without flame, impinging upon combustible objects, may bring them to the point of ignition. It is not so difficult, in consideration of the above facts, to account for the long range at which the effects of a conflagration are propagated. The writer witnessed a practical exhibition of the long range effects of heat radiation at the great fire of April, 1889, at Fifty-ninth Street and Eleventh Avenue, New York, when a large lard refinery burned and the fire spread to an adjoining warehouse, three grain elevators of the N. Y. C. R. R. and two of its covered piers. This is the largest fire that has occurred in New York for many years past. During the height of the fire in the lard refinery, before it had spread beyond, but after the walls had begun to fall, I found the nearest point to watch the fire was 200 feet away, across a vacant lot south, where I could face the blaze only by applying my eye for short periods to the crack of a board fence. (See *Plates 4* and *5*.) The sheet of flame from the fire was at this period at least 150 feet horizontal by 100 feet vertical, and although the wind was blowing away from the fence which shielded me, yet the fence was ignited a short distance away. It is needless to say that the fire department had long since been driven away by the heat and were under shelter.

The temperature of this sheet of flame must have been not far from 5,000° F. to produce such an effect.

We estimated the probable course of our tests as likely to run over several years and to cost fully $10,000. We decided to begin with tests of columns and then proceed to tests of girders and beams, and finally of walls and parti-

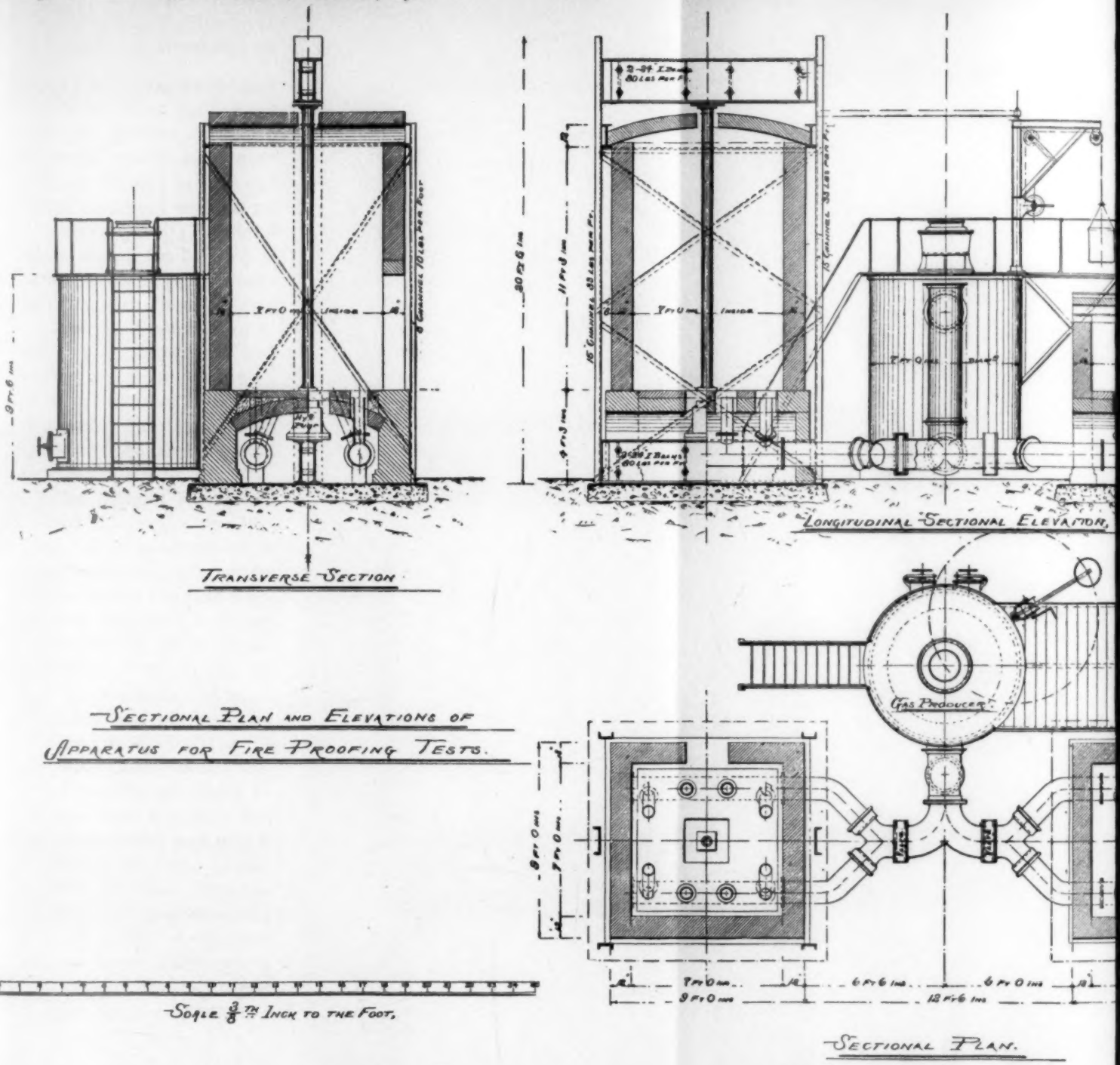
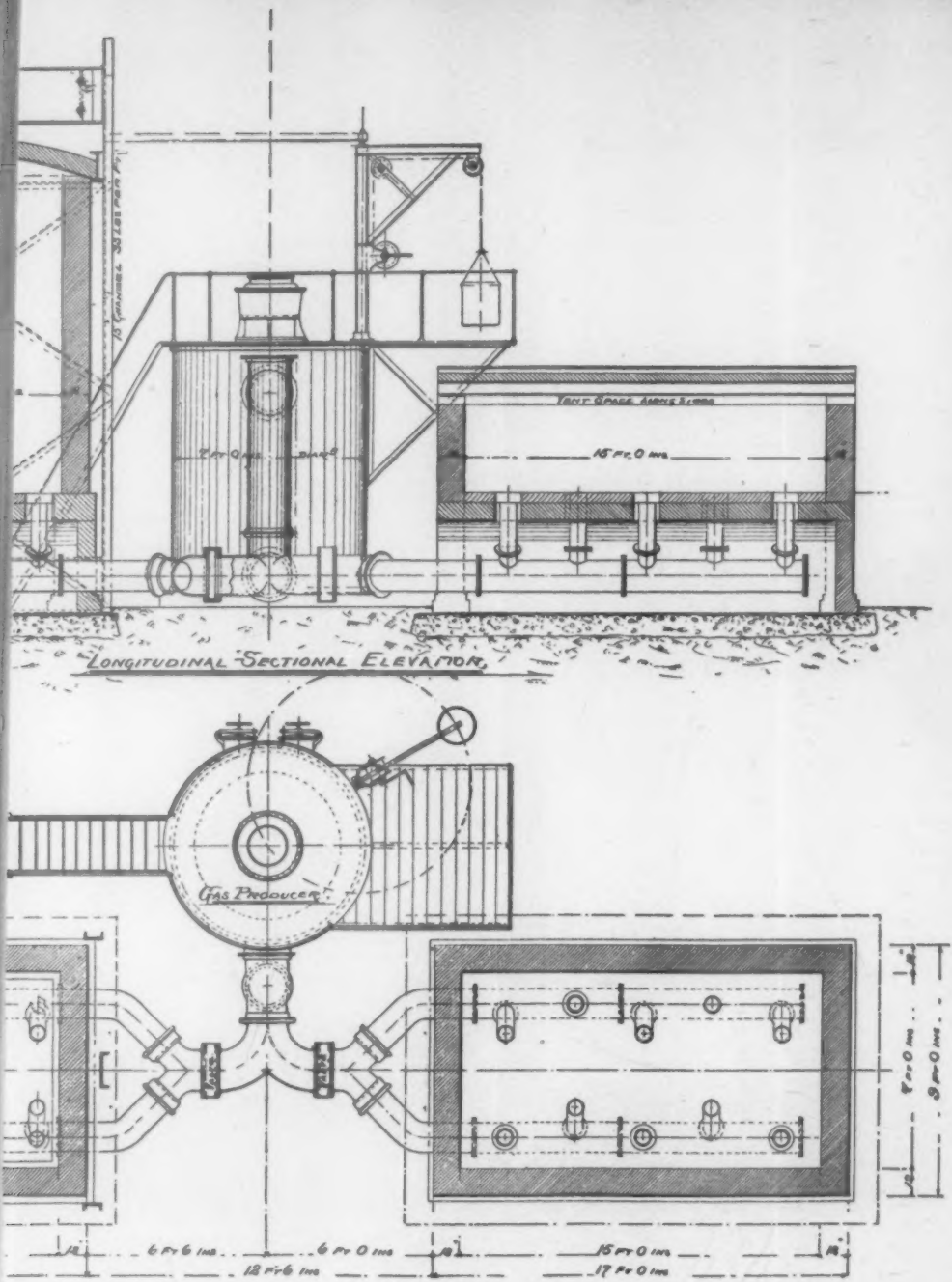


PLATE 7.—Diagram of testing plant.



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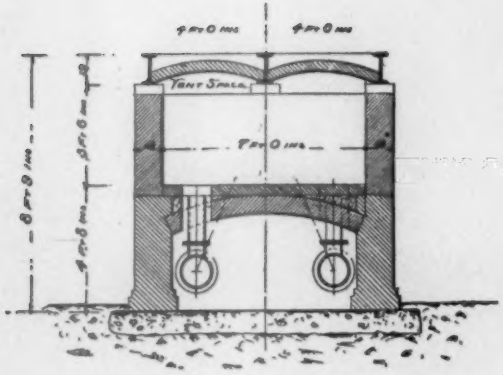


TRANSVERSE SECTION.

tions; and, inasmuch as the main issue we were to settle would be, what kind of protective material or armor around columns, girders and beams should be the standard, the first essential was to ascertain what is the actual nature of the damage caused by fire, or by fire and water conjointly, upon those members without any protection.

Description of Testing Plant.—Our testing plant having been completed late in the spring of this year, we have conducted and completed during the summer the first series of tests, viz.: those on unprotected columns.

The plant consists of a furnace for testing columns and walls and partitions, and a furnace for testing girders, beams and floor arches. A gas-producer, such as is used in iron and steel works, with its attendant boiler, supplies the fuel. There is also a hydraulic pump for applying the working load and a small house for sheltering the pyrometric apparatus.

The column furnace has an arched fire-brick roof, supported independently of the walls, and intended to be permanent. The products of combustion escape through openings between the top of the walls and the arch named. Steel beams under the furnace and one over the top are connected by steel uprights, forming a quadrilateral vertical frame independent of the furnace, and between the upper and lower members of which the column is pinched by a hydraulic ram at the under side. The column passes through the floor and roof of the furnace.

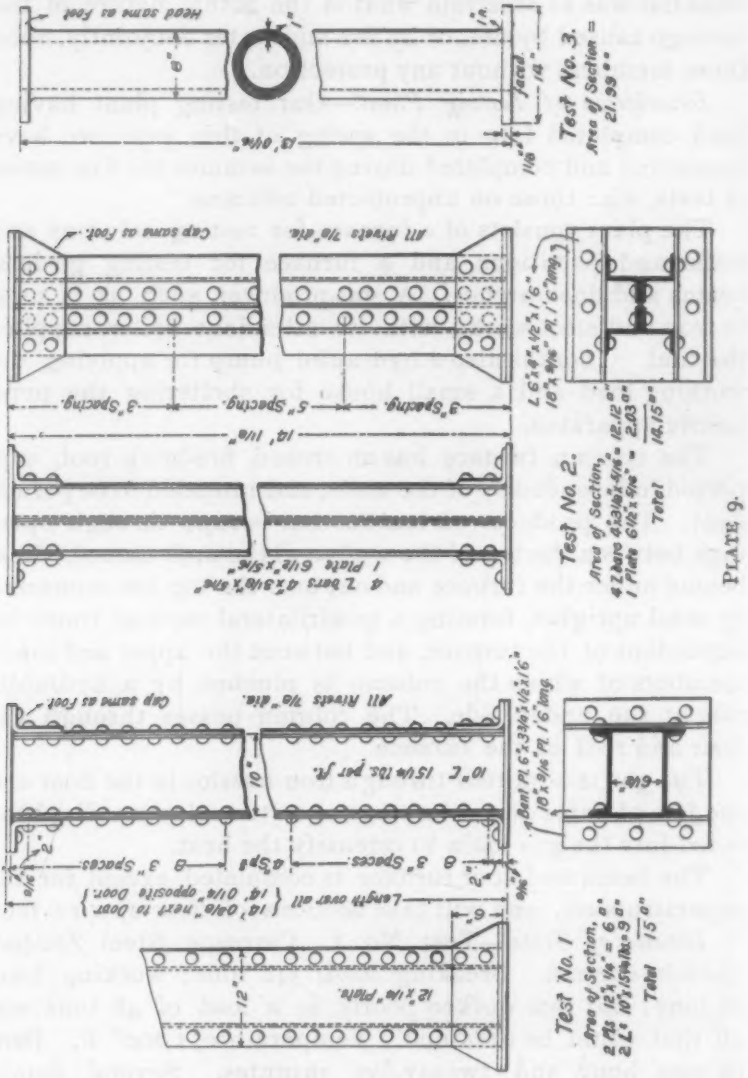
The gas is admitted through iron nozzles in the floor and the jets of flame do not impinge upon the columns. Naphtha is fed into the gas main to intensify the heat.

The beam and floor furnace is completed, except for the superstructure, and will take sections of floor 27 x 12 feet.

Details of Tests.—Test No. 1. Carnegie Steel Zee-bar, 12-inch column. Breaking load, 342 tons; working load, 80 tons; but ram worked poorly, so a load of 48 tons was all that could be obtained. Temperature, 1,200° F. Bent in one hour and twenty-five minutes. Several delays occurred in working the gas.

Test No. 2. Carnegie steel plate and channel column,

12 inches. Breaking load, 303 tons. Tested at working load of 84·8 tons. Bent in twenty-three minutes at a temperature of 1,125° F.



Test No. 3. Cast-iron column from Cornell Iron Works. Cylindrical, 8 inches in diameter, 13 feet long; shell, 1 inch

thick. Safe load, 90·2 tons; tested with load of 84·8 tons. Bent at about 1,100° F. in one hour and ten minutes. No water applied. Slow increase of fire.

Test No. 4. Cast-iron column, same as above. Tested with 84·8 tons load. Bent at 1,550° F., in thirty-five minutes. No water applied. Rapid increase of fire. Eight minutes after the column began to bend it broke in the middle.

Test No. 5. Cast-iron column, same as above. Tested under a load of 84·8 tons.

Heated to 525° F. and water thrown on.

Heated again to 775° F. and water thrown on.

Heated again to 1,050° F., showing red heat, and then water thrown on.

Heated again to 1,300° F., showing red heat, and column beginning to bend, water again thrown on.

No fracture of any kind resulted. The temperature was measured by an Uehling & Steinbart pyrometer.

(See *Plates 8, 9* and *10.*)

The tests will be continued at an early date and will proceed with tests of

Protected columns.

Unprotected columns and beams.

Protected girders and beams.

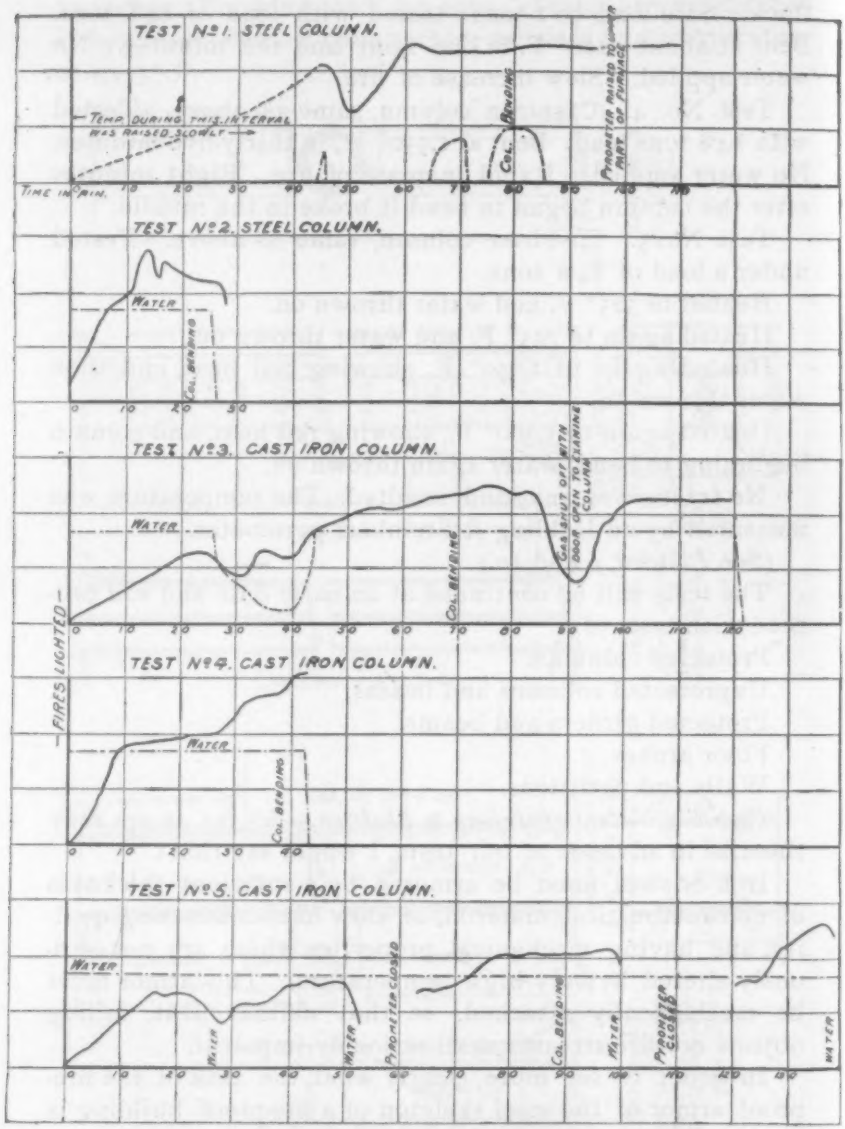
Floor arches.

Walls and partitions.

Probable Nature of Injury to Skeleton.—So far as we may theorize in advance of our tests, I would say that:

Iron or steel must be armored by a sufficient thickness of non-combustible material, of slow heat-conducting quality, and having mechanical properties which are not seriously altered by very high temperature. This armor must be mechanically attached, so that neither heat, falling objects nor fire streams shall seriously impair it.

In order to see more clearly what the task of the fire-proof armor of the steel skeleton of a fire-proof building is to be, we decided in our tests to look first into the effects of fire upon a similar skeleton without such armor. (See *Plates 2* and *3.*) In this matter it is to be noted that the important effects were not those currently reported as



Temperature is indicated by Full Heavy Lines, Vertical Spaces = 500° F.
Hydraulic Pressure by Dash and Dot Lines, Vertical Spaces = 50 tons.

PLATE 10.—Graphical record of tests.

WATER

PLATE 6.—Plant erected to test fire-proofing structural metal in buildings.

PLATE 8.—Views of the columns after the tests.

PLATE 6.—Plant erected to test fire-proofing structural metal in buildings.

occurring in fires. Thus, expansion appears to be of minor importance as a destructive agent. Personally, I consider that what is commonly reported after fires as warping or twisting is improperly so described. The peculiar twists of the steel beams and girders observed in the wrecks of this class of buildings after fires are due to the shock of the fall, the impact of other objects, and such bending as the member obtains while subjected to stress while red hot. It is a mistaken idea to figure to ourselves steel members warping or twisting as strips of paper will do when hung in front of a flame, a phenomenon due to unequal drying. The effect of fire upon iron can be noted in a common stove. The fire-box must be kept lined with fire-brick, otherwise the shell is damaged. The ash-pit must be kept free from live coals, otherwise the grate bars will become sagged. By thus keeping the lower side of grate-bars below a red heat, the upper side may be at times at a red heat and yet no permanent deformation results. If the whole bar gets red hot it sags from the weight of the coal and does not recover its shape on cooling, but assumes a permanent set and deformation. But, doubtless, with a cool ash-pit the grate-bars, under the influence of the fire over them, curve slightly with the convexity upwards, but upon cooling they recover their normal shape.

Nature of Injury to Cast-Iron Columns.—Due, doubtless, to the heavy expense, no such tests as these have ever before been made on a full working scale. The Hamburg tests of 1894 were made on full-sized columns; but, probably from economy, they applied the heat only to a limited portion of the middle of the column, and, though they brought out important facts, they missed the mark at which we aimed; and, furthermore, missed entirely, by the very fact of local heating, the results which we got with cast-iron columns. While we showed similar though more complete results on riveted steel columns, we also showed for the first time the fire conduct of cast-iron columns in a fire with or without water. It is interesting to quote the prediction made by Mr. John C. Freeman, in a paper read before the Engineering Department of Cornell University

in 1894, as to this point (p. 39). Mr. Freeman asserted that the popular idea that hot cast-iron columns shatter like glass when water strikes them, is erroneous, and our tests fully substantiate this view, although we shall not consider it settled until we have experimented on some of the older styles of very thin steel columns. I have not, however, found any one yet who anticipated the quiet and smooth bending effect of a normal load upon a red-hot cast-iron column, just as a heavy lead pipe might be expected to act if used as a supporting column; nor has our provisional conclusion from these tests been anticipated, namely, that there is no particular choice between unprotected cast-iron and steel columns as to their fire value. Both yield by bending at a red heat about in the same manner, and will eventually double up. But the cast-iron column appears, from tests (3), (4) and (5), to have continued to resist; that is, to have retained some sustaining power throughout the period of bending, whereas the steel column ceased almost entirely to resist; that is, lost practically all of its sustaining power as soon as the buckling began. On the other hand, the cast-iron column broke in two after bending a little way, whereas the steel column did not break, and probably would not have broken, even if the bending had been carried completely through. This feature may possibly be noted as a fact in favor of the steel column. It is interesting to note that, when we arrive at the bending heat, it is probable that many fine distinctions are obliterated; that is to say, that it makes little difference whether the columns are accurately bedded, or trued, or plumbed, or whether the quality of the steel or iron is better or worse. While cold, these points are of extreme importance, but at the bending heat their importance disappears. We can understand this by again resorting to the analogy of the lead pipe. If you make a table with three legs—two of wood and the third of lead pipe—and load the table until the lead leg bends, I think you will find that fine distinctions as to the quality of the lead, or the accuracy of the bearing ends of the leg, or the eccentricity of its load, will be largely neglectible unless the leg is very short and thick. Not that

any lack of care was or will be shown in the adjusting of columns for test; on the contrary, the greatest care was shown in these particulars.

I append, in conclusion, the following list of some typical temperatures (Le Chatelier, *Comptes Rendus*, 1892).

	Degrees F.
Bessemer steel converter	2,994
Siemens Martin open-hearth furnace	2,876
Regenerative furnace, crucible steel	2,912
Blast furnace—gray pig	3,506
Siemens glass furnace	2,390
Siemens porcelain furnace	2,498
Incandescent electric lamp	3,272–3,812

An approximate formula for computing the distance at which a sheet of flame will ignite wood by simple radiation, knowing the approximate radiating area of the flame, is as follows:

$$D = \sqrt{\frac{A\,T}{6000}}$$

in which

D = distance between the flame and the wood to be ignited.

A = radiating area of the flame in a vertical plane.

T = temperature of the flame in degrees Fahrenheit.

The speaker illustrated his subject liberally by the use of lantern slides.

[At the close of the discussion which followed the reading of the paper, the meeting passed a vote of thanks to the speaker for his interesting and valuable communication.]

MODERN THEORIES OF FERMENTATION, WITH NOTES ON THE MORPHOLOGY AND CULTURE OF YEASTS.*

By Dr. Francis Wyatt.

[*Concluded from p. 286.*]

I must not allow myself to wander too far into this fascinating field of bygone controversies, but I must dwell upon one point in Pasteur's work, which had a most important bearing on the fermentation industries. He had observed, in some of his determinations, that when yeast and a saccharine solution were kept in an air-free flask, the proportion of yeast produced to sugar consumed was much smaller than it was when a similar solution was kept in a shallow vessel and freely exposed to the atmosphere.

He found that when yeast cells are very young and very vigorous they are able to promote fermentation in a suitable medium out of all contact with air. He also found that mature yeast induces fermentation very slowly under similar conditions, and that the resulting cells are invariably of abnormal shape. Finally, he observed that if really old yeast is employed in air-free media, no cell reproduction at all takes place. The yeast does not die, but it remains dormant, as may be shown by the fact that if the liquid be ærated after some time, either with atmospheric air or oxygen, fermentation and reproduction at once go on.

From all these circumstances, as he saw and understood them, Pasteur gathered that, given a suitable quantity of air, yeast can live by direct absorption of oxygen and can produce carbon dioxide gas without requiring sugar. Directly the air is taken away on the other hand, sugar becomes essential *as a source of oxygen.* To put it more plainly, yeast in the presence of air is a fungus or a mould, whereas, in the absence of air, it is a ferment. If yeast can perform its vital functions more readily when it obtains its oxygen in the free state than when it has for that purpose

* A lecture delivered before the Franklin Institute, January 10, 1896.

to effect the decomposition of large quantities of sugar, its life as a fungus is, of course, the easiest. I have noticed, in my own practice, that if yeast be grown continuously in saccharine solutions under conditions which result in the rigid exclusion of air, fermentation becomes more and more sluggish, and I conclude that, the conditions of life being more severe, the struggle for existence is so acute that vitality eventually succumbs. I have recently had special facilities for conducting fermentations on the large scale in one of our largest breweries, in closed vessels, under what is now known to brewers as the "vacuum process," and I have invariably found that when air is excluded there is a certain stage at which yeast reproduction becomes sluggish. By introducing into the liquid at this stage a regulated supply of pure air, so as to thoroughly ærate it by bringing it into full contact with oxygen, I have found that it undergoes a remarkable change, and that the growth of yeast then increases with great rapidity.

If I accept the theory of Pasteur in this connection, I must conclude that by introducing air I cause the yeast to flourish as a fungus on the dissolved free oxygen. I should also have to admit that the yeast ceases its action as a ferment while the oxygen is present, and simply grows and accumulates vital energy. I cannot, in the light of my practical experience and of general recent progress, however, accept these conclusions in their entirety, and I will endeavor to explain briefly the reason why.

In all his experiments in this direction Pasteur *weighed* his yeast, and I think this was in a great measure a mistake. If he had *counted* the cells he would have been able to refer his results to the amount of effect being produced in any liquid by the action of an unit cell. One of our foremost modern investigators is Adrian J. Brown, and he has concluded in this relation that, when any fermentable nutritive solution, such as malt wort, or a solution of dextrose in yeast water, is inoculated with yeast, and kept at a temperature favorable to its growth, the cells reproduce themselves rapidly for a time. When they cease to multiply, the fermentation of the solution does not stop, but is carried

on by the continued life of the cells already formed. No matter what number of cells may be introduced to start the fermentation, the same maximum crop will be obtained, providing the liquid be the same, and all other conditions equal. These are really most important conclusions, and they are supported by Brown, by a reference to the following experiment: Two flasks were taken, marked A and B, 150 cubic centimeters of the same malt wort were placed in each, and then they were treated with a different amount of the same yeast. The contents of the flasks were thoroughly agitated, and the cells were counted by the hæmatimeter. (The standard volume of the instrument employed was $\frac{1}{4000}$ of a cubic millimeter.) The flask A contained 0·93, and the flask B contained 7·44 cells per standard volume. The flasks were kept at 77° F. until fermentation had completely ceased, when the cells were again counted. In flask A the number of cells per standard volume had increased from 0·93 to 25·24; whereas, in flask B the increase was from 7·44 to 27·08. The rate of increase differs widely, but you will notice that the ultimate number of cells produced was approximately the same.

In another experiment more cells were added to the solutions than the maximum number, two similar flasks of malt wort being seeded respectively with 6·0 and 70·8 cells of yeast per standard volume. Fermentation was allowed to proceed, and, at its close, in No. 1 flask the cells had increased from 6·0 to 24·9, while in No. 2 they had decreased from 70·8 to 68·2. In this experiment 24·9 cells may be regarded as the maximum number that the wort used would grow, and, consequently, with No. 2 flask there is no increase, but an actual diminution, which is probably accounted for by the death and disintegration of some of the cells. It was noted in this and many similar experiments that in the second flask, as well as the first, fermentation proceeded with great rapidity, and as this seems to afford us a method of studying fermentation without multiplication of cells, Brown conceived the idea of applying it to the investigation of the action of oxygen on yeast.

He made a malt wort of 1·065 specific gravity and added

yeast to it in the proportion of 85 cells per standard volume; 120 cubic centimeters of this solution were poured into flask A so as to nearly fill it; its mouth was then stopped in such a manner as to prevent the access of air, but not to impede the escape of carbon dioxide gas; 120 cubic centimeters of the same wort were next placed in a large flask B, of about 1,500 cubic centimeters capacity, so as to simply form a thin layer of liquid on the bottom, through which a current of air could be readily drawn. Both flasks thus had exactly similar contents, but the one was small and was kept free from the air, while the other was large and its contents were subjected to abundant æration. The fermentation was conducted at 67° F., and after the end of three hours was arrested by the addition of salicylic acid. The liquids were distilled and the amount of alcohol produced estimated from the specific gravity of the distillate. In the A flask without æration, 3·35 grams of alcohol had been formed, while in the B flask, through which a continuous current of air had been drawn, the alcohol amounted to 3·56 grams. The number of yeast cells had not increased at the close of the experiment, but slight attempts at abortive budding were observable, particularly in the flask B.

In another duplicate experiment which was made, the fermentable medium was a solution of dextrose in yeast water, seeded with 90 cells of yeast per standard volume. At the end of three hours fermentation was stopped, and the residual sugar in the solution in each flask determined polarimetrically. In A (unærated), 1·96 grams of dextrose had been fermented, while in B (ærated), the quantity of fermented dextrose was 2·32 grams. There was no sign in either of the flasks of any budding or enlargement of the cells.

In a discussion of these results, it was objected that the *mechanical* effect of æration might stimulate the action of the cells in the B flasks, and to meet this objection the following pairs of experiments were made, in which the A flasks were subjected to the action of currents of carbon dioxide and hydrogen respectively, and at about the same rates as the air was passed through the B flasks. The

results were as follows, and the interest attaching to them lies principally in the fact that they show that in every case the most work is done in the presence of oxygen :

"A" flask, with passage of carbon dioxide, 3·99 grams of dextrose fermented.

Companion "B" flask, with passage of air, 4·28 grams of dextrose fermented.

"A" flask, with passage of hydrogen, 2·26 grams of dextrose fermented.

"B" flask, with passage of air, 2·45 grams of dextrose fermented.

You will observe that in these experiments the fermentation proceeded very rapidly, and will understand that it did so because Brown employed such large quantities of yeast. In order to watch the result under slower conditions, he made experiments with fermentation at 44° F. continued for twenty-four hours. Through A flask hydrogen had been passed, and 4·882 grams of dextrose had been fermented; in B flask, through which 190 liters of air had been passed in twenty-four hours, the quantity was 5·289 grams. The fact that there was no multiplication of yeast whatever in any of these experiments affords a striking contradiction to Pasteur's great theory, to which I alluded just now, since it proves that *in the presence of oxygen actual fermentation is more vigorous than in its absence.*

In order to dispel any suspicion of difference in results because of difference in methods of estimation, I may mention that Brown made one important experiment in which he weighed as well as counted his yeast. In this case the two flasks A and B were again employed, and, at the commencement, there were in each flask 87·6 cells per standard volume, and 1·903 grams of filtered, washed and dried yeast per 100 cubic centimeters of the liquid to be fermented. Fermentation resulted in the destruction of 6·20 grams of dextrose in the hydrogen flask, and 7·38 grams in the air flask. No increase took place in the number of cells, but the weight of the yeast, after being filtered, washed and dried, did increase very slightly in each case, that from the hydrogen flask being 2·030 grams, and that from the air flask 2·060

grams. The increase is, however, so small as to be practically negligible; and as it is probably due to assimilation, I think it is quite fair to say that in both cases we wind up with almost the *same weight of yeast*, as well as the same number of cells, and hence that equal amounts of yeast, whether determined by weighing or by counting, ferment more sugar when supplied with air than when deprived of it.

As I have been working on almost the same lines with Brown, I have duplicated many of his results with insignificant variations in my own laboratory during my students' experimental course. It was Pasteur's belief that the weight of the yeast formed during fermentation under varying degrees of aëration, and in proportion to the weight of sugar fermented, was an expression of fermentative power, and he argued that the ratio of yeast to sugar must always remain constant, however much or little sugar is available. As the result of what I have just told you, however, you will see that there is absolutely no direct proportion between weight of yeast formed and sugar fermented, and it is not too much to say that the total fermentative power of yeast was never accurately measured in Pasteur's experiments. For various purposes connected with my professional work, I have carried out numerous fermentations under ærobic conditions, in such a manner as to decompose practically all the sugar originally present in the wort. When I have prevented reproduction by seeding with large excess of yeast, and have added sugar to the fermenting wort repeatedly at intervals, until several times the quantity originally present has been decomposed, I have always found that the weight of the yeast has undergone no increase at the end of the operation. Where are we to look for Pasteur's mistake? I cannot enter into a lengthy dissertation, but I will say briefly that in my own opinion it is entirely attributable to the conditions under which he was working. He used too limited an amount of sugar, and carried on his ærobic fermentations in shallow dishes for altogether too limited a time. He also used cane sugar as the fermentable material, and this is an important argument against him. He did not so fully realize, as we do now, that before yeast can ferment cane sugar, it must first

exercise its hydrolytic functions and invert the sugar, and he consequently made no allowance for the time taken up by this preliminary function. Broadly condensing all these facts, I think that, without intending to cast the slightest reflection on the work of the great master, I have shown good reasons for disputing his "life without air" theory, and for substituting for it, as the basis of our modern theory of fermentation, "that oxygen can be used by yeast cells just as it is used by the ordinary ærobic fungi, and that it is probably essential to their proper and continuous reproduction. They can, however, for a time exhibit their full fermentative functions in a propitious medium, independently of free oxygen."

Turning now from the purely theoretical to the more practical phases of fermentation, as we employ and understand that term in the arts, and more especially in that of brewing, there only remains to me sufficient time to draw your attention to the most salient points connected with the cultivation and examination of beer yeasts, as carried on by the modern brewer.

When a minute quantity of yeast is added to some malt-wort, which has previously been filtered bright, and is then kept in a glass flask at a temperature of about 70° F., it will be noticed after a few hours that bubbles of gas will rise to the surface of the liquid. Gradually the liquid will become more and more turbid, and, later on, in accordance with the variety of yeast used, either a sediment will be observed at the bottom of the flask or a scum will collect at the surface, carbonic acid gas being in the meantime copiously evolved. If the yeast cells be carefully examined under the microscope from time to time while this is going on, it will be noticed that at first the vacuoles which were present in every cell gradually disappear, each cell becoming full and rounded in appearance, owing to the absorption through its cell wall of certain nourishing substances from the wort. Some minute buds will be seen jutting out from the sides of the cells; these buds rapidly grow and soon assume the size of the parent cell, from which they finally become detached, but not before they in their turn have developed

other buds, and these yet others, thus giving rise to little groups or strings of cells. This cell reproduction and growth is due to the nourishment which the yeast derives from the wort; but, as I have already explained, for some time after the yeast cell continues to produce buds, and even after the rupture takes place between the parent cell and the resulting daughter cell, the former will continue to absorb various substances from the liquid.

The actual process of alcoholic fermentation cannot be stated with accuracy, but it probably consists in an absorption of carbohydrate substance by the yeast cell, and the splitting up or transformation of this substance into alcohol and carbonic acid gas, the presence of free oxygen being desirable in order that the cell may continue to properly thrive and grow and put forth buds. During the period of growth a fattening of the cells takes place at the expense of certain assimilable or digestible nitrogenous compounds present in the wort, which may be either salts of ammonia, peptones or amides. If neither of these, but only insoluble albumens be present, no fattening takes place, and the yeast becomes starved, as it were, and perishes. On the other hand, it has been my experience that, if there be present a large excess of these nitrogenous matters, the yeast cells become overfed, and their capacity for reproduction becomes thereby considerably diminished.

There are a large number of species or races of yeasts, and they are all characterized by some special action on the different varieties of sugars, and by some special products as the result of that action. Some species, for example, readily ferment dextrose and lævulose, but exert no direct action on cane sugar. Other species secrete a substance known as invertase, which has the power of splitting cane sugar into dextrose and lævulose, and when they have exercised this preliminary inverting function they next proceed to exercise their fermentative powers on the inverted products. Yet other species contain an enzyme known as glycase, which splits up maltose and malto-dextrines into dextrose, and you will thus perceive that in the ordinary yeasts, as we find them in the fermentation industries, we are called

upon to deal with a mixture of races all endowed with different faculties, some of which may be very valuable, others highly objectionable, and some of which may take place within and others without the cell wall of the organism. There can be no doubt that Pasteur was entirely correct when he stated that every form of deterioration in beer or in wine is associated with some particular organisms belonging to a class of disease ferments. Some forms of this class may be readily distinguished from the true *Saccharomyces cerevicie* by means of the microscope, but there are others which are not so distinguished because they have all the outward characteristics of pure yeast. Incalculable numbers of these false ferments are always present in the atmosphere, as well as on the surface of all fruits, so that if sweet, unboiled brewers' or distillers' wort be freely exposed to the air, it will, in the course of a few hours, without the addition of yeast, manifest all the outward signs of fermentation. This fermentation will be mainly carried on by wild yeasts and spores of bacteriæ and moulds, and after a few days, if left to itself, the wort becomes quite turbid, is covered with a thin film, emits a disagreeable smell, and rapidly putrefies. If, however, the sweet wort is boiled with hops before exposure to contamination, all the spores which may have been derived from the outside air are killed by the heat, and the wort, being thus sterilized or rendered free from all foreign germs, is more likely, when mixed with pure yeast, to undergo a true alcoholic fermentation.

I have said that our commercial yeasts are a mixture of races, but at the present time it is an easy matter to procure a pure ferment of any desired single special race or character. This stage of our progress we owe to Dr. Hansen, to whom I have already referred, and whose work on the cultivation of absolutely pure yeast of one particular race and of ascertained quality has been brought to a most successful issue. When Pasteur had established his theories as to the cause of disease in beer, Hansen conceived the idea of cultivating pure yeast from a single selected yeast cell, as opposed to Pasteur's suggested plan of purifying yeasts by the addition of certain antiseptics, which were supposed to

have a selective action, and to work upon the bacteriæ and leave the yeasts unharmed. Since Hansen made his first practical demonstrations in the brewery in 1883, carefully selected types of yeast, from pure cultures made by his method, have been introduced into many of the leading breweries of the world with the most marked success. The great advantage offered by Hansen's discovery is due to the fact that the several varieties of each species of ferment can be separated, and that, while they cannot microscopically be distinguished from each other, they are all found, when so separated and used on a practical scale, to give entirely different fermentation products, both as to flavor, brilliancy, attenuation and clarification.

If the microscope does not enable us in some instances to differentiate one form of yeast from another, it has yet enabled us to discover that under certain conditions the yeast cell, instead of throwing out a bud, multiplies itself in another way, its protoplasm dividing itself into four masses, termed acrospores. Each of these acrospores surrounds itself with a cell wall, and the whole of them are finally set free by the dissolution of the cell wall of the parent. Now, Hansen observed that pure and normal bottom fermentation yeast forms spores at 77° F. only after some days, whereas nearly all the wild species which communicate objectionable qualities to beers are capable of forming acrospores at this temperature in a few hours. You will see, without difficulty, that this is a most interesting and important fact, and will understand that it may be used as the base of a method for the practical analysis of brewers' yeast, which I will briefly describe.

We will suppose that we are called on to examine a sample of suspected brewery yeast. A small quantity is spread on a sterilized block of plaster of paris, and this block is placed in a flat, covered glass dish containing water to keep it moist. The dish is placed in a thermostat or forcing chamber, and kept at a temperature of 77° F. for forty hours. At the end of that time it is carefully examined under the microscope, and if any wild yeast be present, the spores will be seen as round bodies within the cell wall.

According to Hansen's carefully worked out experiments, the principal species of budding fungi with which the true *Saccharomyces cereviciæ* is most commonly associated or contaminated are:

Saccharomyces pastorianus No. 1, which imparts to beer a disagreeable bitter taste and very unpleasant odor, together with a turbidity most persistent in its character.

Saccharomyces pastorianus No. 2, a very feeble yeast, which does not appear to impart any disagreeable odor or flavor, but which prevents clarification.

Saccharomyces pastorianus No. 3, a yeast of very similar character to the No. 2, but productive of more turbidity.

Saccharomyces ellipsoideus and *Saccharomyces exiguus*, which occur on the skins of ripe grapes, and give to beer a very persistent turbidity and a disagreeable, bitter and astringent after-taste.

Saccharomyces mycoderma cereviciæ, a yeast which forms a film on the surface of beer and reproduces itself by budding or by spores, which has a very limited fermentative action and does not directly cause acidity, but which is a powerful oxidizing agent and causes alcohol to be transformed into carbonic acid gas and water.

The species of bacteriæ which may occur in beer are too numerous to mention, but those best known to us arise from yeast contamination or atmospheric infection, and are the *Bacillus amylobacter*, *Bacterium termo*, *Bacterium aceti*, *Bacterium lactis*, *Sarcina* and *Micrococci*. Of the species most frequently met with in old beer, the principal are the ropy ferment, the color bacterium, and certain forms of vibrio, spirillum, etc. The whole of these disease organisms constitute an army which constantly worries and harasses the brewer and keeps him ever on the alert, since they generally develop themselves very freely under favorable conditions, more especially in the finished beer after it has been some time in cask or bottle. I will not weary you with a catalogue of the vices of these germs, but will be satisfied to state that *Bacterium aceti* has the power of converting the alcohol of beer into acetic acid; that *Bacterium lactis* attacks the residual saccharine matter and converts it into lactic

acid, and that the latter, being acted on by the *Bacillus amylobacter*, is, in its turn, converted into butyric acid.

The preservation or contamination of brewers' yeasts, or the maintenance of a given ferment in a state of purity and health, depends almost entirely on the nature of the fluids in which it is cultivated.

The foods of yeasts must be capable, by assimilation, of producing heat and of forming tissue, and they must be made up of a judicious mixture of certain carbohydrates, albuminoids and minerals, in suitable proportions, and in a truly soluble and readily assimilable form. The carbohydrates contained in brewers' worts are the sugars and dextrines produced by the transformation of starch under the influence of the enzyme diastase; the albuminoids are the peptones and the amides, or soluble nitrogenous substances of malt; the minerals are phosphates, sulphates and chlorides, either derived from malt naturally or added to the liquid artificially.

Bearing these elementary principles in mind, we cannot fail to institute the well-worn comparison between good and bad brewers' worts and fertile and sterile lands. Let the wort contain the necessary constituents in suitable proportions, and the yeast plant sown in it, under ordinary and proper conditions of cleanliness and care, will be vigorous and healthy; but let there be either a lack or an abnormal excess of either of the essential components, and the true yeast plant will deteriorate with great rapidity. This deterioration or weakening will allow other germs, for which the liquid is a more propitious medium, to usurp the yeast's place and flourish in its stead. This, of course, is in accordance with a perfectly natural and general law, which applies not only to yeast, but equally as well to all other plants and to man and animals.

Of the two kinds of fermentation known to brewers, the top fermentation is carried on at temperatures between 55° F. and 75° F.; the yeast is eventually conveyed to the surface, and the process generally lasts from four to seven days. The bottom fermentation takes place at temperatures between 40° F. and 52° F., the yeast, by reason of its

greater specific gravity and the sluggish nature of the fermentation, ultimately subsiding completely to the bottom of the fermenting vessel, and the process lasting from ten to fifteen days. Ale is produced by the top fermentation, lager beer by the bottom fermentation, and the scientific grounds on which preference is given to the latter are: That at the low temperature used, fewer organisms develop which are detrimental to the qualites of the beer, and that a sounder and better-keeping beer can, in consequence, be produced.

The difference in appearance between top and bottom yeast is slight—so very slight, in fact, that the one can safely be said to be undistinguishable from the other by means of the microscope.

The kind of microscope best adapted for the use of brewers and distillers is one that will give a magnification of from 600 to 1,000 diameters with a clear and well-defined picture. The comparative purity of yeasts can be determined by it only very roughly and approximately, because good and bad yeast types may have identically the same microscopical appearance; but there are certain characteristic forms of wild yeasts and of harmful bacteriæ which can at once be identified, and for which it is imperative to keep constant watch and ward. Two or three samples of yeast should always be taken for microscopical examination from the tubs after the surface has been skimmed off, and a number of fields from each sample should be subjected to rigorous scrutiny. The preparation of the sample is so easy and expeditious that it is an easy matter for the brewer, who takes pride in his fermentations, to perform several investigations each day. A very small portion of the yeast sample is carefully and thoroughly mixed up in any convenient vessel with some pure distilled water. By means of a rod with a rather fine point, a small drop of the mixture is transferred to a glass slide, and evenly and thinly spread out over a small surface, which is then covered with a thin cover-glass. The slide having been placed upon the stage, the objective is brought into position by means of the fine screw, so that, with a bright light, mirrored from a clear sky or from an incandescent lamp, the organisms become plainly visible.

The yeast cells should be uniform in size and shape, full and plump-looking and transparent, and must contain few, if any, vacuoles or granulations. The cell's wall should be thick and free from pittings, and stand out well against the field. There should be no signs of budding, and no dead or shriveled cells should be present. In order to detect the existence of dead cells, a drop of methylene blue solution may be added to the dilute mixture of yeast under examination. This will stain the dead cells instantly, and will leave the living matter entirely unaffected. It is also a good plan to add to the sample to be examined a small portion of caustic soda or potash solution, in order to dissolve any hop resins or albuminoids that might otherwise be taken for bacteriæ.

In general terms it may be stated that a really good seed yeast should contain no bacteriæ of any kind; but I need hardly say that it is extremely rare to find samples, even from our best breweries, which are not more or less contaminated with some form of foreign or wild growths. As a rule, any sample which contains more than twenty of such forms in every ten fields should be rejected, and a sample in which more than two long rods appear in the same number of divisions should invariably be condemned.

As I have already taken up a great deal of time, I can only give you a very brief outline of the process of cultivating pure yeast from a single cell; but I will, nevertheless, endeavor to make it comprehensible. The operation is, of course, commenced in the laboratory. A minute quantity of the yeast is cultivated in small flasks with sterilized wort. As soon as the fermentation has commenced, the newly formed cells are drawn off to another flask, which contains sterilized water, and which is then well shaken so that the yeast cells get equally dispersed. A drop of this liquid is next examined under the microscope, then dropped quickly into another small flask containing sterilized wort gelatine, liquefied at a temperature not exceeding 85° F. After gentle shaking, this liquid is examined under the microscope, and if it does not show more than one or two cells in a field, one drop of it is spread evenly over the inside of

a cover-glass, divided into squares and placed in a "Boetchers" moist chamber. This chamber consists of a glass ring with ground rims; on the one rim is fastened a cover-glass, the other is to be fastened with vaseline to a glass slip, on which is put a drop of water. As soon as the wort-gelatine has stiffened on the cover-glass the ring is placed on the glass slip, and thus isolated. The whole of this operation is done in a box with glass sides and a sliding door, just big enough to make it possible for the experimenter to manipulate in it, these precautions being taken in order to obtain an atmosphere as quiet and as free from dust as possible. Generally, two or three "Boetchers" chambers are made for each experiment, in case an accident should happen to one of them. As soon as the chambers are finished they must be examined under the microscope with a very low power, so that the cells are just discernible, in order to ascertain whether they are placed so that single ones can be selected and separate growths or cultures be developed. The various cells are then examined, and marked with a colored ring on the outside of the cover-glass round each single cell. This being done, the chamber is placed in an incubator, and kept at a constant temperature of about 85° F. If each colony is now examined, it will be seen to be as large as the head of a pin, and each is now introduced singly into small Pasteur flasks containing sterilized wort. If a culture from only one species of yeast is required, four or five flasks will be sufficient; if from more, four or five flasks are required for each kind.

The Pasteur flasks, the "Boetchers" chamber containing the yeast growths, a tweezers and some small pieces of sterilized platinum wire are all kept in the sterilized air-box. The ring being removed from the cover glass, one of the pieces of platinum wire is taken with the tweezers and with it one of the marked yeast groups is picked out. The wire is then dropped into the wort contained in one of the Pasteur flasks, and the latter is closed as rapidly as possible. In the same manner the wort in the other flasks is inoculated with one of the different yeast groups selected. The flasks containing the pure culture are so marked as to show

from which cells they originate, and placed in the thermostat at 85° F. for forty-eight hours. The contents of the flask are then examined, and those of them which show the same characters are mixed and transferred into larger flasks, and in this manner the work is continued in the laboratory until about 9 gallons of fermenting wort are distributed over four large Pasteur flasks made of copper.

The operations in the laboratory having come to an end, the selected yeast is next cultivated in sufficient quantities for practical use in the brewery, by means of an apparatus similar to that used by Hansen-Kuhle. It is constructed on the same general idea as that upon which Pasteur devised his flask, and is so arranged that it can be erected in the fermenting cellar itself. It consists of three parts:

(1) The wort chamber.

(2) The yeast cylinder.

(3) The aërating compartment, consisting of an air pump and air receiver, the latter with filter of cotton-wool attached.

The wort cylinder consists of a drum with a lid, which, for the purpose of cleanliness, can be readily removed. Inside the cylinder is fixed a copper steam coil, by which the wort can be sterilized. By means of a valve the cylinder is connected with the air in the receiver, and the air is passed through the filter near the valve. It is necessary that a constant pressure of sterilized air be present in the cylinder to prevent infection of the wort by the entrance of outside air. The wort cylinder is connected with the fermenting cylinder by a pipe, and is enclosed in a jacket with an intervening space filled with cold water for the purpose of cooling the wort. The fermenting cylinder is constructed nearly in the same manner as the wort cylinder. It has a perfectly air-tight lid, through which passes an agitator with two end blades, the one being provided with an india-rubber scraper, which sweeps the bottom as well as the sides when in motion. From the lid there issues a double bent pipe, which, when its valve is opened, communicates with the interior of the cylinder, its free end standing in a vessel of water to secure a constant over-pressure.

A little below the lid a horizontal pipe is fixed, whereby the interior of the cylinder can be connected with a vertical glass tube, the top of this latter being connected with a filter, and the bottom with another horizontal tube passing through the lower part of the cylinder. On the side of the cylinder provision is made for introducing the yeast through the pipe.

The air is filtered before it enters the pump, and later on it is more perfectly purified through the filters on the cylinders. The receivers must be strong enough to stand a pressure of 80 pounds. After the wort has been sterilized, well aërated, and refrigerated in the wort cylinder, it is introduced into the fermenting cylinder, which has previously been sterilized and supplied with the suitable quantity of pure yeast. The yeast is stirred up now and then while the wort is passing over, and it is necessary in fact to keep the contents of the cylinder in movement until the fermentation has commenced. During the fermentation, a slight current of sterilized air is allowed to pass through the filter into the cylinder to force out the carbonic acid gas, which has been developed during the fermentation. When the fermentation is finished part of the yeast will have accumulated on the surface, and part of it will have fallen to the bottom. Beer is now drawn from it until nothing but foam comes from the faucet, and then sterilized wort is again introduced into the cylinder until the lower mark on the glass tube is reached. The rouser being put in motion the yeast is stirred up, and the whole process is repeated until yeast sufficient for starting a fermentation in about ten barrels of wort has been obtained. The apparatus is kept in continuous work, and it is only necessary that the yeast taken from the cylinder be constantly subjected to microscopical control. Directly the presence of any impurities is observed, the cylinder must be cleaned, sterilized, and a new pure culture introduced.

Although the cultivation of pure yeast has not yet made much progress amongst the practical brewers in this country, it is quite certain that its advantages only require to be fully understood by them in order to make it an indis-

pensable part of their processes. Its adoption will supersede all the present attempts to secure immunity from the troubles that now constantly arise from the uncertain action of false ferments or wild yeasts and bacteriæ, and will ensure the production of brighter, more stable, and better-flavored beers of any desired type by our modern breweries.

I think I have now gone far enough to establish that all the disagreeable qualities of malt beverages are the directly resulting products of ferments foreign to the true yeast, and to demonstrate that such defects may be obviated without difficulty by excluding these foreign forms from the fermentative medium.

I have not pretended to trace in detail the ways in which, owing to various peculiarities, our present methods have diverged from those that preceded them, because to do this would require an amount of learning and a scope of thought to which I cannot possibly pretend. I have endeavored to give you some general perceptions of great discoveries and truths, and I shall be fully satisfied if some of you seek to follow out these truths and prove them by evidence that will satisfy your own minds. You will agree with me that in such a complicated subject the wider any generalization is, the greater will be the chance of apparent exceptions; and when, as in this instance, certain theories cover a vast amount of space, the exceptions may be innumerable, and yet not destroy in any way the fundamental accuracy of the theory itself. If the general proposition is admitted, it necessarily follows that the adoption of the methods devised by science for the correction of errors and the ultimate attainment of perfection are mere matters of time and education. Men will come and men will go, but true science will remain. It has already sustained the shocks of empires and will always outlive the struggles of rival theories and creeds. Of it we may truly say that it is built upon a rock and must stand forever.

NIAGARA ON TAP.*

By T. Commerford Martin.

[*Concluded from p. 302.*]

We have now reached the point at which we can actually see the energy of Niagara converted into electrical current. There is the water flowing steadily into the intake canal from the main Niagara River, gliding by so smoothly and swiftly. There are the gates through which the diverted water flows to the penstocks. There are the turbines at the foot of the penstocks. There is the shaft set in revolution by the headlong fall of water, and there is the dynamo itself, spinning like a big, fat teetotum, and which, in the very act of spinning, changes the mechanical energy or gravitational effect into electro-magnetic energy and thus yields us that which, for want of a better word, we call current. Curiously enough, the energy that we have just caught up from the river outside, we are going to head back again in the very direction that is contrary to the direction of the water's flow —just as though we had taken a wild Indian runner, seized him by the shoulders and swung him around so quickly that he kept on faster than ever back over his own tracks. We want now to deliver this energy on the spot as well as at Buffalo and lots of other places even more than 20 miles away, and we want to prove, on a grand scale, the absurdity of that wise old adage which says that you cannot grind with water that has gone by.

The next thing after reclaiming this truant energy by means of this machinery is to deliver it to the people who want it, and first of all we must carry it to the switchboard. The switchboard is always the first link between a power-house or central station and the outside world. To it generally lead the current conductors of all the dynamos; from it start, and to it return, all the smaller conductors and wires that deliver the current to lamps, motors and other devices.

*A lecture delivered before the Franklin Institute, January 3, 1896.

It is provided with switches which enable you to put one dynamo in connection with all the circuits of your customers, or all the dynamos if necessary, on one circuit. With these switches when you open one circuit you automatically close another, and in short, you can make so many changes with one turn of a little handle, that what happens may well be compared to the old-fashioned game of "General Post." The switchboard is, in fact, a clearing-house, a warehouse, a big retail store that receives its goods wholesale and instantaneously splits them up for consumption. Besides doing all this, it serves to protect the apparatus from lightning and sudden shocks, and by means of tell-tale instruments placed on it, you can see at once how everything is going, whether the dynamos are running properly and whether the customers are getting all the current they want and of good quality. Now, in almost all places, the switchboard is a tall wall or slab of marble or mahogany, not unlike a big front door with lots of knobs, knockers and keyholes on it; but at the Niagara power-house it takes the form of an imposing altar or tomb—perhaps we might call it a local option platform, or, having in mind its controlling functions, we may compare it to the bridge of an ocean steamer, while the man in charge or handling the wheels answers to the navigating officer.

The ingenious feature is employed of using compressed air to aid in opening and closing the switches. The air comes from a compressor located at the wheel-pit, and driven by a small water motor. It supplies air to a large cylindrical reservoir, from which pipes lead to the various switches, the pressure being 125 pounds to the square inch. So far as the main switches are concerned, every electrical engineer will realize that it is a serious thing to manipulate a dynamo circuit loaded with 5,000 horse-power of current. It is comparable to changing front right about face with a headlong charge of a squadron of heavy cavalry. It appears, however, to be done very successfully and quietly by the mechanism shown. Another interesting point is, that the measuring instruments on the switchboard do not measure the whole current, but simply a derived portion of

determined relation to that of the generators. In other words, the operator on the platform cannot touch a dangerous circuit, and he simply acts as a sampler or taster, much as one does who tests with tube the purity of Croton water or digs a gouge into a big cheese. All told, less than one-thirtieth of a horse-power gives him all the indications required. To the switchboard current is taken from the dynamos by heavy insulated cable, and it is then taken off by huge copper bus bars, which are carefully protected by layers of pure Para gum and vulcanized rubber, two layers of each being used, while outside of all is a special braided covering, treated chemically to render it non-combustible. The calculated losses from heating in a set of four bus bars carrying 25,000 horse-power, or the total output of the first

Main power-house and transformer house.

five Niagara generators, is only 10 horse-power. The cables and bus bars are mainly the work of Mr. W. M. Habirshaw, one of our leading manufacturers of insulated wires and cables.

Those who have not a very definite idea of the insulation by which a current is cribbed, cabined and confined within its proper channel, the copper, can arrive at a clear understanding of it from this cable, of which about 1,200 feet were supplied for the power-house. It has not broken down until between 45,000 and 48,000 volts of alternating current were applied to it, which will show that the insulation is a pretty effectual strait-jacket. There are 427 copper wires in that cable, consisting of 61 strands, laid up in reverse layers, each strand consisting of 7 wires. Next to the strand of copper is a wall of rubber, $\frac{1}{4}$ inch thick,

double coated. Over this is wrapped absolutely pure rubber, imported from England, and known as cut-sheet. Then come two wrappings of vulcanizable Para rubber, answering, we will say, to shirt and trousers. Then there is a wrapping of Poole-made cut-sheet, and on top of that are two more rubber coats. This is then taped, covered with a substantial braid and vulcanized. The object in using the cut-sheet is to vulcanize it by contact, in order to make it absolutely water-tight. This cable weighs just over 4 pounds to the foot, of which 3 pounds are copper and 1 pound insulation.

We have thus advanced far enough to get our current on to the bus bars, and the next step is to get it from them out of the power-house. This final work we do by simply extending our bars, so to speak, and carrying them across the bridge, over the canal, into what is known as the transformer house, that quiet little place resembling a porter's lodge at the gate of a mansion. It is here that the current received from the other side of the canal is to be raised in potential so that it can be sent great distances over small wires without material loss, for that is one of the purposes underlying all the plans of the Cataract Construction Company. We shall touch on this presently. Meantime, we may note that the Niagara Falls Power Company itself owns more than a square mile around the power-house, upon which a large amount of power will be consumed in the near future by manufacturing establishments of all kinds, and that it is already delivering power in large blocks, electrically, to one factory for the production of aluminum, and to another for the production of the remarkably efficient abrasive called carborundum, an improved kind of emery, for which a great many uses are being found. Special apparatus for this work has been built by the General Electric Company. The current for the production of aluminum is made direct by passing through static and rotary transformers, while the Acheson carborundum process uses the pure alternating current. Besides this, the trolley road from Niagara to Buffalo is taking already part of its power from the Niagara power-house by means of

rotary transformers. For these and other local uses the company has constructed subways in which to carry the wire across its own territory. These subways are 5 feet 6 inches high, and 3 feet 10 inches wide inside. They are built up with 12 inches of Portland cement and gravel, backed up with about 1 foot of masonry at the bottom and extending about 3 feet up each side. The electric conductors are carried on insulated brackets or insulators arranged upon the pins along the walls. These brackets are 30 feet apart. At the bottom of the conduit manholes are holes for tapping off into side conduits, and along it all runs a track upon which an inspector can propel himself on a private trolley car, within screens, if necessary. Thus is distributed locally the electric power for which the consumer pays the very modest sum of $20 per electrical horse-power per annum, delivered on the wire, or $12 for a turbine horse-power, a rate which is not to be equalled anywhere,* I imagine, in view of the absolute certainty of the power, free from all annoyance, extra expense, or bother of any kind on the part of the consumer. This is why industries of all kinds needing power in substantial quantities are beginning to flock to Niagara.

But there is a converse aspect of this power question. While on the one hand the power attracts customers, on the other hand there are many places and many customers that would rather have the cheap power brought to them. This is a fact we are all familiar with in many spheres of life and labor. Some Europeans have come to this country, but for the vast majority our cheap wheat and beef must be taken to them. Some cotton mills exist in the South, but the bulk of the cotton must be carried to New England or old England. Some coal is burned near the pit's mouth, but the largest part goes far from the beds yielding it. All this is for the reason that in so many cases it is cheaper and better to take power to the people than to bring the people to the power. Now, Buffalo and Rochester and Albany

* This is where the power is developed by the tenant himself, *i. e.*, the tenant putting in his own hydraulic machinery and water connections.

need power in large quantities, but obviously it is advantageous for many reasons to give them cheap power where they are, rather than bring them to Niagara, and if this can be done, it is just as though Niagara itself were in their precincts, instead of being scores or hundreds of miles away. If the power is in the shape of wheat and beef, we need ocean steamers; if it is coal, we need tracks and locomotives; if it is electricity, all we need is a fine wire, so slim that at a distance of 200 or 300 yards you could not possibly see it.

It is a curious fact that the proposal to transmit the energy of Niagara a long distance over a wire should have been regarded with so much doubt and scepticism, and that the courageous backers of the enterprise should have needed time to demonstrate that they were neither knaves nor fools, but simply brave, far-seeing men. We have to-day parallel instances to Niagara in the transmission of oil and natural gas. Oil is delivered in New York City over a line of pipe which is at least 400 miles long, and which has some thirty-five pumping stations *en route*, the capacity of the line being 30,000 barrels a day. All that oil has first to be gathered from individual wells in the oil region and delivered to storage tanks with a capacity of 9,000,000 barrels of oil. Chicago, Philadelphia and Baltimore are centers for similar systems of oil pipe, running hundreds of miles over hill and dale. Now, how improbable such a plan would have seemed if propounded at the beginning of this century to the plain captain of a New Bedford whaler. As for natural gas, that is to-day sent in similar manner over distances of 120 miles, Chicago being thus supplied from the Indiana gas fields, and the gas has its pressure raised and lowered several times on its way from the gas well to the consumer's tap, just as though it were current from Niagara.

We must not overlook some of the fantastic schemes proposed for transmitting the power of Niagara before electricity was adopted. One of them was to hitch the turbines to a big steel shaft running through New York State from East to West, so that where the shaft passed a town or factory, all you had to do was to throw on a belt or some

gear-wheels and thus take off all the power you wanted. More reasonable, though, perhaps, not much less infinitely expensive, was the plan to have a big tube from New York to Chicago, with Niagara Falls at the center, and with the Niagara turbines hitched to a monster air compressor, which should compress air under 250 pounds pressure to the square inch in the tube. As under the other plan, all you had to do, if needing power, was to tap this compressed air tube and get what you wanted. But Niagara certainly was not destined to blow her own trumpet in that longitudinous way.

So far as actual electrical long-distance transmission from Niagara is concerned, it can only be said to be in the embryonic stage, for the sole reason that for nearly a year past the Power Company has been unable to get into Buffalo, and that not until recently has it been able to arrive at acceptable conditions, satisfactory alike to itself and to the city. Work is now to be pushed at once, and, in less than a year, power from the Falls will be in regular delivery to the local consumption circuits at Buffalo, 22 miles away. For the transmission of the first 10,000 horse-power to Buffalo it has been decided to use the pressure or potential of 10,000 volts, with such arrangements at each end that 20,000 volts can be used if necessary. There will be no difficulty about this work. The company has carefully secured rights of way for its pole lines, and the conditions have already been dealt with in other places, as many of you are aware. The 105 miles transmission from Lauffen to Frankfort, in 1891, was at the pressure of 40,000 volts. Many mines in this country, up in the mountains, now have their power brought to them over miles of line. From the San Antonio Cañon, in Southern California, electric power, generated by the melting snows of the mountains, is sent at a potential of 10,000 volts to San Bernardino, nearly 30 miles away, for both light and power. At Guadalajara, Mexico, the General Electric Company has a transmission circuit of 18 miles and 11,000 volts; and it has another at Pachuca, under construction, of 23 miles. A famous high-voltage, alternating-current transmission in Europe is that from the

Falls of Tivoli, on pole lines, to Rome, a distance of 17 miles. This year has witnessed the celebration, by the city of Sacramento, Cal., with beating of drums, firing of cannon, street parades, per-fervid oratory and lavish illuminations, of a transmission of power at 11,500 volts from Folsom, 23 miles away. Salt Lake City is now to be supplied with power from eight lakes up in the famous Wahsatch Mountains. It will be seen that the Buffalo problem is well within easy handling, and, with growing knowledge and better apparatus, the conditions for such work improve all the time. For example, the circuits are carried by triple-petticoated insulators of porcelain, and these are now cured to withstand a pressure of 90,000 volts before a puncture can be made. In short, a line efficiency between Niagara and Buffalo of at least 90 per cent. is looked for, so that for every 10,000 horse-power passed into the step-up transformer on the brink of the canal at Niagara, 9,000 horse-power will be taken off by the step-down transformers in the receiving station at Buffalo. It is also believed that the power can similarly be sent to Albany, on poles along the Erie Canal, at a loss of about 60 per cent., so that 10,000 horse-power at Niagara would represent 4,000 horse-power available for distribution at the junction of the Erie with the Hudson, 300 miles away.

But the question arises, and has been fiercely discussed, whether it will pay to send the current beyond Buffalo; whether it is worth while to reach out to Rochester, Syracuse and Albany; whether, in fact, it is even worth while to take it to Buffalo, the center of cheap coal, cheap oil and cheap natural gas. I, for one, cannot help thinking that Niagara power will compete favorably with other power in Buffalo; for recent official investigations, made by Mr. H. A. Foster, have shown that steam-power in large bulk, under the most favorable conditions, costs to-day in Buffalo $50 per year per horse-power, and upwards. Evidently, Niagara power, starting at $10 on the turbine shaft, or, say, $18 on the line, has a good margin for effective competition with steam in Buffalo.

Now, as to the far-away places. The well-known engi-

neers, Prof. Houston and Dr. Kennelly, have made a most careful estimate of the distance to which the energy of Niagara could be economically transmitted by electricity. Taking established conditions, and prices that are asked today for apparatus, they showed that even in Albany or anywhere else in the same radius—330 miles from the Falls—the converted energy of the great cataract could be delivered cheaper than good steam-engines on the spot could make steam-power with coal at the normal price there of $3 per ton. I do not now propose to go into controversy or details, but I do make bold to say that when such conclusions are reached and find support, the time is certainly on us when we must deal with these long transmissions of electrical energy as new factors in the industrial commercial life of the State and nation.

You must have been impressed with the fact shown in this brief running comment on the situation, that what this enterprise at Niagara aims to do is not to monopolize the power, but to distribute it; and that in this way it makes Niagara more than it ever was before, the common property of the citizens.

After all is said and done, very few of us ever see the Falls, and then only for a chance holiday once in a lifetime; but now the useful energy of the cataract will be made cheaply and immediately available, every day in the year, to hundreds and thousands, even millions of people, in an endless variety of ways. If this be not to make Niagara a common heritage, then I do not know what the phrase means.

Perhaps some of you remember the story about Miss Porter, a member of the family that was once in possession of the Niagara region. She was traveling in Europe, and at dinner one night her companion said: "Oh, if you are an American, I suppose you have seen Niagara Falls." She turned on her escort haughtily, and fixing a stony glance on him, said: "I own them." We can now all say with Miss Porter: "We own them."

We must not omit from our survey the Erie Canal, in the revival and greater utilization of which, as an important

highway of commerce, Niagara power is expected to play no mean part. In competition with the steam railway, canals have suffered greatly the last fifty years. In our own country, out of 4,468 miles of canal built at a cost of $214,000,000, about one-half has been abandoned, and not much of the rest pays expenses, which is what you might expect when you race a mule barge against a fast freight train. Yet canals have enormous carrying capacity, and a single boat will hold as much as twenty freight cars can, so that obviously if you give the canals cheap, good power, you can do for them what has now been done for the street car lines by devoting the horses to the canning industry. In other words, give the canals cheap electric power and we shall again have them a powerful factor in the equalization and minimizing of freight rates. I am glad to say that this has already been recognized by our own State authorities, who have agreed to conditions by which Niagara energy can be used to propel the canal boats at the rate of $20 per horse-power per year. Where steamboat haulage for 240 tons of freight now costs about 13 cents a boat mile, it is estimated that electric haulage will cost not to exceed 10½ cents, while, with the energy from Niagara at only $20 per horse-power per year, it will cost much less. Evidently this is a task worth attempting. Some two years ago the first attempt was made in this country and on the Erie Canal, with the canal boat *F. W. Hawley*, when the trolley system was used with the motor on the boat, as it is on an electric car, driving the propeller as if it were the car wheels. But the better and cheaper way is to modify the plan of hauling your boat from the tow-path, and this is what is now being done with the electric haulage system of Mr. Richard Lamb on the Erie Canal at Tonawanda, near Niagara. Imagine an elevator system working lengthwise instead of vertically, and you will get a rough idea of the arrangement. There is placed on poles a heavy fixed cable on which the motor truck rests, and a lighter traction cable is also strung, that is taken up and paid out by a sheave, as the motor propels itself along, and pulls its canal boat to which it is attached. If boats come from opposite direc-

tions they simply exchange motors, just as they might mules or locomotives, and go on without delay. There is no reason why the whole of the Erie Canal should not be equipped this way for freight, and if the canal be deepened, a so much higher rate of speed can be obtained that it might even pay poor people to travel again by canal boat as it once did our grandfathers and fathers. I can imagine worse traveling experiences than a trip along the picturesque Erie without dust or smoke, at the rate of 5 or 6 miles an hour on the broad deck of a comfortable "canal greyhound."

We might digress on many such pertinent and allied themes; as, for example, the operation of the New York Central Railroad by electric power from Niagara, but must leave them, not only for the present moment, but also for the coming years, which alone can show all the wonderful possibilities of this noble, and, I am firmly convinced, profitable enterprise. Before I close there are two other points, however, to which I ought to direct attention. One is to the fact that, on its property at Niagara, the power company has already begun the development of the new village, called Echota, a pretty Indian name, which signifies "Place of Refuge." I believe it is Mr. Howells who, in kindred spirit, speaks of the "repose" of Niagara. It was laid out by Mr. John Bogart, the New York State engineer, and embodies all that is best in sanitation, lighting and urban comfort. That which was waste wilderness blossoms as the rose, not figuratively, but literally, and it does not need the eye of faith to see here the beginning of that which is destined to be the beautiful center of one of the busiest, cleanest, prettiest and healthiest cities in the Union. The workingman, whose factory is not poisoned by smoke and dust, whose home was designed by McKim, Mead & White, whose streets and parks were laid out by distinguished engineers, and whose leisure is spent within sight and sound of lovely Niagara, has little cause for grumbling at his lot.

My final comment is upon the interesting strategy with which our American company has also pre-empted the great

utilization of the Canadian share of Niagara's energy. Thus far I have dealt only with the work done and contemplated on our own side of the river, but I now show you the plan approved by the Canadian Government for the company's work on their side. This plan, not yet carried out, proposes the erection of two power-houses of a total ultimate capacity of 125,000 horse-power. Each power-house is fed by its own canal, and is, therefore, an independent unit. Owing to the better lay of the land, the tunnels carrying off the water discharged from the turbines will have lengths, respectively, of only 300 and 800 feet, thus avoiding the extreme length and cost unavoidable on our side. In one of the designs it has been suggested to put the dynamos underground alongside the turbines, at the bottom of the shaft; but I hardly think that this damp, rheumaticky, but ingenious scheme will be adopted. With both the Canadian and the American plants fully developed, no less than 350,000 horse-power will be available, while the stationary engines now in use in New York State represent only 500,000 horse-power. Yet the 350,000 horse-power are but one-twentieth of the 7,000,000 horse-power which Professor Unwin has estimated the Falls to represent theoretically. If the 350,000 horse-power were estimated at $20 per year per horse-power, and at Niagara should replace the same amount of steam-power at $50, the annual saving for power in the State would be more than $10,000,000 per year—an accomplishment that within a very few years may give Niagara a stronger claim to the admiration of the Empire State than it has ever had before.

Let me not transgress any longer on your time and attention with diagrams and data, but once more, by way of conclusion, emphasize the truth that this splendid engineering work leaves all the genuine beauty of Niagara untouched. It may even help to conserve the scene as it exists to-day, for the terrific weight and rush of waters over the Horse-shoe Fall is eating it away and breaking its cliff into a series of receding slopes and rapids; so that even a slight diminution of the whelming mass of wave

will, to that extent, lessen disruption and decay.* But be that so or not so, those of us who are lovers of engineering can now, at Niagara, gratify that taste in the unpretentious place where some of this vast energy is reclaimed for human use, and then, as ever, join with those who, not more than ourselves, love natural beauty, and find with them renewed pleasure and delight in the majestic, organ-toned and eternal cataract.

[The lecture was profusely illustrated with stereopticon views.]

A PRACTICAL PLAN FOR SAND FILTRATION IN PHILADELPHIA.

By Allen Hazen, C.E.

[*A report to the Woman's Health Protective Association of Philadelphia.*]†

In accordance with your instructions I have examined the water-works system of Philadelphia, to determine whether or not it is feasible to purify the water of that city by means of sand filtration as commonly practiced in Europe, and without the use of alum or other coagulants, and if so, to determine as nearly as may be what cost would be thereby involved.

I wish to acknowledge at the outset my very great obligation to Mr. John C. Trautwine, Jr., Chief of the Water Bureau, who has placed the resources of his office at my disposal, and without whose co-operation this report would have been impossible. I am also indebted to Mr. Amasa Ely, his assistant, for personal attention in examining the various grounds mentioned in this report, and to other gentlemen of the Water Bureau for their uniform courtesy and attention in furnishing maps, statistics and data at their disposal.

* Professor Shaler, of Harvard, has suggested the buttressing of the cavities under the falling sheet of water, with masonry, so as to hold up the superincumbent strata.

† Printed in the *Journal* by permission of the Association.

The question of filtering the water supply of Philadelphia has already been considered at the direction of your Association, by Joseph B. Rider, C.E., who presented a report thereon, dated April 29, 1895. Mr. Rider advocated the adoption of some form of sand filtration, but was inclined to favor a plan somewhat at variance with the most approved European practice.

In the short time available for this examination it has been possible to make but a superficial examination of the problem, sufficient only to determine the feasibility of the general process suggested; and this report, so far as it relates to particulars of arrangement of works, etc., must be considered as suggestive rather than in the nature of definite recommendations.

This is particularly the case, as the whole subject of future water supply for Philadelphia was most exhaustively considered by Mr. Rudolph Hering, an engineer of great eminence and ability, during the years from 1883 to 1886; and as a result of his studies he recommended to the city the introduction of water by gravity from upland sources, supplemented by water pumped from the Delaware River from a point above the most serious points of pollution. Mr. Hering did not consider at length the filtration of the present sources, as he did not consider the then existing evidence as sufficient that filtration would adequately purify such waters. The additions to our knowledge of the nature and results of filtration during the last ten years have materially changed the aspects of the case, and Mr. Hering has himself indicated that if he were reconsidering the subject he would give serious attention to the filtration of the present supply.

The advantages of a gravity supply from upland areas, where the water is not subject to pollution by sewage, are very great, and the project recommended by Mr. Hering is not to be put lightly aside to make room for the latest ideas concerning the purification of polluted waters obtained from sources near at hand, and you will thus readily understand that it is impossible for me at this time to recommend the adoption of any system. I have simply canvassed the

ground in a preliminary way to determine the possibilities of filtration.

In case the city should take the matter up, it would be desirable and necessary to have the various suggested localities surveyed and examined by test pits, and to have plans prepared for the various works involved. It would probably be found, upon further study, that the general plans here suggested could be modified with advantage in many important particulars, and a plan could be worked out which could be taken as representing the most favorable system of filtration. This plan should then be compared in all its phases with the plan recommended by Mr. Hering, taking into account changes in the cost of construction and of the interest to be paid for borrowed money, etc., which may have occurred in the ten years since Mr. Hering's report; and it would be only after such a comparison, which is quite beyond the scope of the present report, that a reliable opinion as to the expediency of the introduction of filtration could be given.

PRESENT SOURCES OF SUPPLY.

The city of Philadelphia now derives its water from the Delaware and Schuylkill Rivers, 94 per cent. being taken from the Schuylkill and 6 per cent. from the Delaware. The Schuylkill above the intakes has a drainage area of 1,900 square miles, and the population upon the water-shed above Philadelphia in 1890 was about 350,000, or 185 per square mile. The most important points of pollution are as follows:

Town.	*Population. (Census of 1890.)*	*Distance above intake. Miles. (Queen Lane.)*
Conshohocken	5,470	8
Norristown	19,791	12
Phœnixville	8,514	23
Pottstown	13,285	39
Reading	58,661	60
Pottsville	14,117	103
Total	119,838	

Urban population on water-shed, 63 per square mile.

An effort is now being made to treat and purify the sewage of Reading before its discharge into the river; but there is no assurance that this treatment as yet is adequate. Aside from Reading, all sewage produced upon the watershed is discharged directly into the streams.

The water from the Schuylkill for Philadelphia is pumped from two pools formed in the river by dams within the limits of the city. The sewage from portions of the city was formerly discharged into these pools. An intercepting sewer has been constructed, which takes sewage to a point below a dam below the lowest pumping station. The district served by this intercepting sewer is sewered by what is known as the separate system. That is to say, the rain water and sewage are removed by separate systems of carriers, and I am informed that little, if any, sewage is discharged from the city sewers at any time into the river above the intakes. The river banks above the city limits, and the west side of the river, where the latter forms the boundary, directly opposite the city, are occupied by manufacturing establishments discharging directly into the river.

The use of water from the Schuylkill at the present intakes has been regarded by every competent authority investigating the subject for many years as most objectionable, and the use of water from such a polluted source should be abandoned at the earliest possible moment.

The Delaware River above the water-works intake has a drainage area of 8,100 square miles, with a population in 1890 of about 600,000, or 74 per square mile. The most important places which may pollute the river are as follows:

Town.	*Population. (Census of 1890.)*	*Distance above intake. Miles.*
Burlington, N. J.	7,264	11
Bristol, Pa.	6,553	12
Mount Holly, N. J.	5,376	15
Bordentown, N. J.	4,232	21
Trenton, N. J.	57,458	26
Lambertville, N. J.	4,142	41
Point Pleasant, Pa. (Point suggested by Mr. Hering as source of water for Philadelphia)		50

Phillipsburg, N. J.	8,644	75
Easton, Pa.	14,481	75
South Easton, Pa.	5,616	76
Bethlehem, Pa.	6,762	86
South Bethlehem, Pa.	10,302	86
Allentown, Pa.	25,228	91
Mauch Chunk and East Mauch Chunk, Pa.	6,873	121
Hazleton, Pa.	11,872	140
Port Jervis, N. Y.	9,327	140
Total	184,130	
Square miles of water-shed		8,100
Urban population per square mile		23

The Delaware River is tidal as far as Trenton. The rise and fall at the intake is said to be about 6 feet. Most of the city sewage is discharged 4 miles or more below the intake; but Frankford Creek, only 1 mile below, receives a large amount of sewage, which flows with it into the river, and a number of sewers serving local population discharge very near, and even above, the intake. It is thought that at ordinary stages of the river, the flow is sufficient to prevent the tide from carrying sewage matters up stream for any considerable distance, but when the natural flow of the river is small, the up-stream movement of the river must be considerable.

I consider it desirable that the intake should be carried far enough up river to be above the highest point to which considerable quantities of sewage from the Philadelphia sewers may be carried by the tide. Whether the present intake fulfils this condition or not could be determined by numerous float experiments, and particularly by repeated bacterial examinations of the water from various points in the river, particularly at times of spring tide and of minimum flow of the river. Such examinations have not been made, but are desirable at as early a date as practicable, to determine the best location for works.

Aside from this possible tidal pollution, the Delaware River is much less polluted than the Schuylkill; its flow is greater; its water is softer; it is less subject to local pollution, and, in every way, it is more desirable as a source of water supply than the Schuylkill; and the same is equally

true whether the waters of each are used in their raw condition, as at present, or if each of them should be filtered by equally good systems of filtration.

SITES FOR FILTERS.

In general topography the land upon which the city of Philadelphia is built rises gradually from the Delaware River. The Schuylkill River cuts through the highland back from the Delaware, and has but a narrow valley. The various pumping stations upon the Schuylkill are surrounded by abrupt hills, and, with but few exceptions, there are no opportunities for the construction of sand filters near them. The exceptions mentioned are not important; for, while considerable quantities of water might be filtered upon land immediately adjoining the Queen Lane and Belmont pumping stations, the areas are inadequate for the filtration of the quantities which will be required for supplying the respective districts, and it will be better to establish filters at other points where all the areas necessary in the respective cases are available at one point.

While the river bottom furnishes no adequate sites for filters, such sites can be found upon the higher and comparatively flat land a short distance back from the river. In utilizing such sites the force mains from the pumping station would be taken to filters constructed upon land above and near the respective reservoirs, and at such elevations as to necessitate as little extra pumping lift as possible. The water would be filtered and then drained from the filters into the respective reservoirs.

At Belmont an area of land a little higher than the reservoir is available, great enough for all possible requirements. A part of this area is park property, while a part is agricultural land and could probably be secured by the city upon reasonable terms.

The Fairmount pumping station, and the Fairmount, Corinthian and Spring Garden reservoirs, are in a closely built-up portion of the city, and are surrounded by lower ground, so that no suitable sites for filters are available in their immediate vicinity.

An area of land between Lehigh Avenue and Clearfield Street, and between Twenty-eighth and Thirty-first Streets, and extending for a little beyond the latter, is owned by the city, having been purchased as a reservoir site. The reservoir, which was to have been called the Cambria reservoir, has not been, and probably will not be, constructed, as the Queen Lane reservoir, in a measure, takes its place. The city owns 45 acres of land in this place, suitable for filter sites, and an additional area immediately adjoining it is now used for agricultural purposes, and could probably be secured. Filters constructed upon this land could be reached from the Spring Garden pumping station, and also, if necessary, from the Queen Lane pumping station, and the effluent would be at a sufficient elevation to drain into the largest of the city reservoirs, the East Park reservoir. The land now owned by the city is sufficient to allow the construction of filters with an effective filtering area of 30 acres with all accessories, and with a maximum filtering capacity of 90,000,000 gallons per day, and with the purchase of other suitable land this capacity could be increased at least one-third.

Another available site for filters is found above the Queen Lane reservoir, where, without going beyond School Lane and Wissahickon Avenue, an area is available sufficient to allow the construction of filters with an effective filtering area of 40 acres, and with a maximum capacity of 120,000,000 gallons per day.

Still another and higher site for filters is available north of the new Roxborough reservoir. I have not maps to show the exact area of this tract, but it is certainly sufficient to meet any reasonable requirements for a long period of years.

Along the Delaware, at the Frankford pumping station, and for many miles above upon the river bank, there are excellent and ample sites for filters. To utilize these sites filters might be constructed in excavation below the level of the river, but it would probably be better to construct filters upon the natural river bank, at an elevation of from 10 to 20 feet above tide water, and to raise the water from the river

by means of centrifugal or low-lift pumps. The filtered water would then flow to the present pumping engines, and be pumped by them as at present, and, if additional capacity should be required, by others, to the various reservoirs, or directly into the pumping mains.

SYSTEM OF DISTRIBUTION.

I have not had time to study in detail the system of distribution in Philadelphia, nor is such a study essential to the direct purpose of this report. The following suggestions as to a revised arrangement of districts are based upon the report of the Bureau of Water for 1891, where a proposed future system is outlined.

The first, or Belmont district, comprises that part of the city west of the Schuylkill River, has an area of 21 square miles, and is supplied from the Belmont pumping station upon the Schuylkill River. The estimated population in 1890 was 100,000.

The second, or Roxborough district, is east of the Schuylkill River, and comprises that part of the city above an elevation of 165, city datum. It has an area of 23 square miles, and had a population in 1890 of 70,000, and is supplied from the Roxborough pumping station. At the present time the Roxborough pumping station is supplying a larger area and population because water is let down from it to lower levels; but as this involves pumping of the water to an unnecessary height, it will be desirable to shut off these lower areas and to supply them from the Queen Lane reservoir as soon as the latter is ready for full use.

The third, or Queen Lane district, comprises land on the east side of the Schuylkill, more than 60, but less than 165 feet above city datum, but not including the higher parts of what may be called the Frankford district. This third district, which is in part—and will soon be entirely—supplied from the Queen Lane Reservoir, has an area of 18 square miles, and its population in 1890 was 208,000. The remaining 29 square miles of high land in the city, most of which is agricultural land, and having as yet only a slight

population, need not be considered further at the present time.

The fourth district includes all that part of the city below the level of 60 feet, city datum, and is now supplied by the Fairmount and Spring Garden pumping stations, and from the Frankford pumping station (the latter including land up to a level of 90); it covers 38 square miles, and had a population in 1890 of 670,000. This is by far the largest part of the city, and is capable of being supplied either from the Schuylkill or the Delaware, or, as at present, from both. The three first mentioned districts, that is, Belmont, Roxborough and Queen Lane, are much more readily supplied from the Schuylkill than from the Delaware.

The rather numerous high-service districts served by secondary pumpage are not here considered, as securing a pure water at the primary stations involves supplying the same to all secondary systems dependent upon them.

To supply the district below 60, city datum, with filtered water, it will be possible, as mentioned above, to filter the water from Spring Garden station on the site proposed for the Cambria reservoir, and to filter the water pumped at the present Frankford pumping station through filters in its immediate vicinity, or it may be better to go to a point further up the Delaware and construct a new pumping station and filters upon a site particularly adapted to them, and to pump the water from this point into the mains supplying the lower part of the city.

RESERVOIRS.

The city of Philadelphia is supplied with water from elevated reservoirs filled from the rivers by pumping. That is to say, the water pumped is carried direct to reservoirs, and the reservoirs are connected with the system of pipes leading to the consumers. At the present time there is an exception to this arrangement in that water for a small part of the city is pumped directly into the mains from the Spring Garden pumping station; but this is a temporary condition, which will not be continued after the Queen

Lane pumping station and reservoir are ready for full service.

The objects accomplished by these reservoirs are twofold: (1) they assure an abundant quantity of water at all times; and (2) the storage improves the quality of the water supplied. In so far as they relate to quantity, they serve to balance the fluctuations of consumption during the different hours of the day, so that the pumps can be operated at a constant rate while the consumption fluctuates from hour to hour; and they also serve as a reserve to supply the city in case of breakage or other accidents to the pumping machinery or mains, or for use in case of unusual conflagration or other excessive demands.

In so far as the reservoirs serve to balance the different rates of consumption at different hours of the day (and this is one of their most important functions), the reservoirs at Philadelphia are very much larger than is necessary. The city has eleven considerable reservoirs, with an aggregate nominal capacity of 1,400,000,000 gallons, equivalent to six or seven days' supply at the present rate of consumption. Several of the reservoirs, however, are not in condition for full service, and the actual quantity of water held in reserve does not exceed 1,000,000,000 gallons, or five days' supply, while reservoirs with an available capacity of one-half of one day's supply are ample to balance the hourly fluctuations in consumption.

In regard to the necessity of maintaining so large a quantity of water for emergencies, it might be well to mention that the water-works in many large cities, including such cities as Detroit and Indianapolis, are operated without any reserve whatever of this nature, the water being pumped directly into the mains as required, without storage. It is necessary in such cases to provide a pumping capacity considerably in excess of the actual maximum consumption, to allow for accidents to any part of the machinery, and practical experience has demonstrated that, with reasonable precautions, it is possible at all times to maintain an adequate supply. As a rule, and within certain limits, additional pumping machinery is cheaper than additional reser-

voirs, and the advisability of maintaining so large reservoir capacity, simply with reference to maintaining the quantity of the supply, may be seriously questioned.

The second function of the reservoirs, perhaps even more important than the first, is that of improving the quality of the water. All the water, with the above-mentioned exception, is pumped to the reservoirs, and it ordinarily remains in them for several days. During these days much of the mud contained in the water is removed by sedimentation; although, after heavy storms, the water supplied from the reservoirs is often very muddy; and, judging from the experience of other cities, and by tests of Dr. Bolton of water from the East Park reservoir, the greater part of the bacteria are also removed, in part by sedimentation, and in part by death, as the conditions in reservoirs are not favorable for the propagation of pathogenic germs, and the larger the reservoir the greater the improvement thus effected. If Philadelphia had reservoirs many times as large as the existing ones, and were able to use them in rotation, it is probable that a reasonably pure, or even an entirely satisfactory, water could be secured from them, even from the present polluted sources; and if the reservoirs had been smaller than they are, the city would have suffered much more severely than it has from the evils of contaminated water. From this standpoint, the ample reservoirs are extremely fortunate and none too large.

In case pure water is furnished, by filtration or otherwise, the conditions with reference to the city's reservoirs will be radically changed. The water will not then be further purified in the reservoirs, and there will be no object in pumping all of the filtered water first to the reservoirs; but it will be quite as satisfactory to pump the water directly into the mains and allow it to go direct to the consumers. By connecting these mains with the present reservoirs it will be possible to operate the pumps at a constant rate, as it is always desirable to do. When more water is pumped than used, as during the night, the excess will go to the reservoirs, gradually filling them; while during the day hours of heavy consumption, when more water is used than is

pumped, the excess pumped during the previous night will be available from the reservoirs to supply the deficiency. The reservoir capacity needed to maintain this service need not necessarily exceed one-third or one-half of one day's supply.

Algæ growths, dependent upon sunshine, are much more abundant in pure water than in ordinary river waters, and, in case the supply is filtered, it will be a serious question whether it will not be desirable to cover the reservoirs by roofing or otherwise, so far as they are directly connected with the distributing system. The necessity of covering would be equally great with any system of filtration—with mechanical filtration as much as with sand filtration. Lawrence and Poughkeepsie, supplying filtered water, use open reservoirs, but a certain amount of algæ growths results. This growth is not particularly unhealthy, but it sometimes becomes disagreeable to the senses.

CONSUMPTION OF WATER.

The population in Philadelphia for 1895, assuming that the increase was at the same geometric rate as it was from 1880 to 1890, was 1,164,000; and the quantity of water pumped, as shown by the pumping records, was 77,819,013,610 gallons or 212,760,673 gallons per day, or 183 gallons daily for every person in the city. In the report of the Water Bureau for 1895 is given a somewhat larger estimate of the population, and a correspondingly lower estimate for the consumption per capita, namely, 162 gallons. Whichever estimate is correct, it is only possible to agree most heartily with the present able Chief of the Water Bureau and with his predecessors, and with every one who has seriously considered the matter in recent years, that this consumption is excessive and entirely beyond the reasonable requirements of the city, and it should and could be reduced at once, by proper measures, to a very much lower figure, probably one-half of the present consumption. It is often alleged that the increased use of baths and other domestic arrangements requiring water largely increases the consumption, and that the rapid increase of manufacturing operations demands

large quantities of water, and that the increase in consumption is to be accounted for in these ways.

The most careful studies show, however, that even in the best class of modern houses, with the most liberal number of fixtures, with reasonable use of water, the consumption does not exceed 30 gallons per capita, or one-sixth of the present consumption in Philadelphia. The demands for water for manufacturing purposes, although undoubtedly larger than formerly, are inadequate to account for the alarming increase in consumption. This increase can only be accounted for by the deliberate or careless waste of water due to a wrong method of charging for the same.

Consider, if you please, what would happen to the city gas works if bills were collected according to the size of the house and the number of fixtures, the charge being the same whether gas was used in an economical and modern manner or whether every jet was lighted and allowed to burn all night, and all day long, too, for that matter. You will see that with such a system gas would be deliberately wasted on every hand and the consumption would increase to several or many times the normal and proper amount. As the works would not be operated at a loss the rates would be raised to cover the needless use of gas, and would be much higher than would be necessary under economical conditions. This condition of affairs is so absurd that it is difficult to give it serious consideration; but it is precisely what is being done in the Water Department in spite of the urgent protests and appeals of the present Chief and of his predecessors for the substitution of a more rational and business-like basis.

The remedy for this most unfortunate condition of affairs is simple, and consists in adopting the same principles in the sale of water that are already followed in the sale of gas. Every water service should be metered, and the quantity of water used charged for at a rate sufficient to pay for its collection, purification and distribution; and when this is done I venture to predict that your consumption will be reduced one-half; that everyone will have water in abundance, and that all persons except those who are now drawing

water largely in excess of their legitimate demands will be served at a less cost than at the present time. The advantages of this arrangement are so obvious, and will accrue with such uniformity to all parties involved, that it seems incredible that the waste of water has been allowed to go so far without adopting means for preventing it.

NATURE OF FILTRATION PROPOSED.

The filters which I have under consideration are the ordinary sand filters, similar to those in use at London, Hamburg, Altona, Liverpool, Amsterdam, Rotterdam and many other cities. They will consist of water-tight basins, with masonry sides and a water-tight pavement for a bottom, on which will be placed underdrains surrounded by gravel, and upon this a layer of sand. The water is to be brought over the sand by suitable devices and filtered downward through it and afterward collected by the gravel, when it will flow through the underdrains to a suitable regulating apparatus for controlling the rate of filtration and loss of head, and thence to the reservoirs or pumps.

The walls of the filters are to be constructed of solid brick masonry, or a cheaper rubble masonry might be used, lined with brick. The bottoms will require to be water-tight, and can, perhaps, best be made by a thin layer of concrete, with a water-tight asphalt covering above. The pressure sustained will be very much less than in the present reservoirs, and a lighter bottom can thus be used.

Sand and gravel suitable for filtration do not exist upon or near any of the sites proposed for filters, except, possibly, sites upon the Delaware, and these materials will require to be brought in from a distance. Crushed stone can be secured at market rates, and bar or bank sand is also a regular article of commerce in Philadelphia. In the case of the construction of the filters, however, it will, perhaps, be better to have specially equipped boats or barges at the points from which sand is originally secured, provided with the necessary equipments to wash the sand and prepare it for placing in the filters, so that no waste material need be transported to the site of the filters. I examined numerous

samples of sand now being brought into the city for building purposes, and I am confident that no difficulty will be experienced in securing an abundance of sand of the quality required.

I consider that the climate in Philadelphia is not severe enough to necessitate the use of covered or vaulted filters, and I have, therefore, made my estimate for open filters. The question as to whether or not sedimentation will be necessary or desirable as a preliminary to filtration cannot be readily settled without a more extended and minute acquaintance with the qualities of the water of the two rivers. From my observations and inquiry, however, I am inclined to think that sedimentation will be unnecessary with the waters of the Delaware, although desirable with the water of the Schuylkill.

In connection with each set of filters for the Schuylkill water provision is made for a receiving basin, into which the water will be pumped and from which it will flow to the filters. These basins will hold one-fourth of a day's supply, and a considerable amount of sedimentation will take place in them, which will probably be sufficient.

The Schuylkill is ordinarily comparatively clear, and could then be filtered without preliminary sedimentation. It is only occasionally when the water is high that very turbid water is pumped, and it should be remembered that these times of turbidity will rarely, if ever, occur at the same time as the maximum consumption, and it will thus be possible to allow the filters to operate at a rate below the maximum when the water is turbid.

I assume that the average daily yield for each acre of effective filtering area for all seasons of the year, including the times when it is out of service for the purpose of being cleaned, will be 2,000,000 gallons. It is further assumed that at times of maximum consumption 50 per cent. more water will be used than the average for the year; and at such times the filters will be operated at a rate of 3,000,000 gallons per acre daily. Draughts of higher rates than this will occur for short periods only, and the deficiency at such times can be made up from the reservoirs.

CHESTNUT HILL
FILTERING AREA
UPPER ROXBOROUGH RES.
Roxboro
LOWER ROXBOROUGH RES.
ROXBOROUGH PUMPING STA.
Schuylkill
Mt. Airy
Ashbourne
Cheltenham
Rockledge
Bustleton
Torresdale
Mt. Pleasant
Oak Lane
Lawndale
FRANKFORD RES.
FILTERING AREA
Holmesburg
GERMANTOWN
W. Manayunk
MANAYUNK
FILTERING AREA
RES.
QUEEN LANE PUMPING STA.
Cynwyd
Falls of Schuylkill
Wayne Jc.
Tacony
FILTERING AREA
FRANKFORD PUMPING STA.
FRANKFORD
Palmyra
FILTERING AREA
Germantown Jc.
RES.
Coopersville
Bridesburg
FILTERING AREA
BELMONT RES.
PUMPING STA.
EASTPARK RES.
SPRING GARDEN PUMPING STA.
RES.
RES.
PUMPING STA
FAIRMOUNT RES.
WEST PHILADELPHIA
Darby
River
Paschallville
Schuylkill
CAMDEN
GLOUCESTER
DELAWARE RIVER
MAP OF
PHILADELPHIA
SHOWING
PRESENT INTAKES, PUMPING STATIONS AND RESERVOIRS
TOGETHER WITH
PROPOSED FILTERS
AND CONNECTIONS.
NOYES & HAZEN,
CONSULTING ENGINEERS,
BOSTON, MASS.
AUG. 1896.
SCALE OF MILES
0 1 2 3 4 5
BRADLEY & POATES ENG^RS N.Y.

The rate of filtration is substantially the same as that actually followed in many European cities, even in cases where there is no adequate reservoir capacity and where the rate of filtration varies with the consumption. With the construction proposed such variations will be entirely unnecessary, and filtration can be maintained at a uniform rate for long periods, and under these conditions there is every reason to believe that the best results will be obtained at the rates suggested.

POPULATION AND QUANTITY OF WATER TO BE PROVIDED.

The population of Philadelphia in 1880 was 847,170. In 1890 it had increased to 1,046,946. Assuming that the increase from 1890 to 1900 is at the same rate as for the ten years before 1890, the population in 1900 will be 1,294,000. For the purpose of estimating the quantity of water required I assume that the population will be 1,300,000, and that of this number 800,000 will be resident in the low district; 260,000 will be resident in the district supplied from the Queen Lane reservoir; 100,000 in the Roxborough district, and that 140,000 people will occupy the Belmont district west of the Schuylkill River.

I have further assumed that the average consumption of water for all seasons of the year will have been reduced by the introduction of meters to 100 gallons per capita, but that at times of maximum consumption as much as 150 gallons per capita daily may be required, making a total filtering capacity required of 195,000,000 gallons. This quantity of water is much less than that now being used, but I believe it is ample for all purposes with a reasonable system for the sale of water.

ESTIMATES OF COST.

The following estimate of cost of works required to filter the quantity of water mentioned in connection with the various pumping stations has been made up from approximate data, and while not exact, the figures are upon ample basis, and will be sufficiently close to the truth for your purpose. The estimates are as follows, by pumping stations:

Belmont pumping station, 7 acres of filters; capacity, average, 14,000,000; maximum, 21,000,000 gallons daily.		
Land now owned by the city.		
Receiving basin	$35,000	
Filters	254,000	
Piping and connections	28,000	
Total		$317,000
Roxborough pumping station, 5 acres of filters; capacity, average, 10,000,000; maximum, 15,000,000 gallons daily.		
40 acres of land	$40,000	
Receiving basin	28,000	
Filters	198,000	
Piping and connections	34,000	
Total		$300,000
Queen Lane pumping station, 13 acres of filters; capacity, average, 26,000,000; maximum, 39,000,000 gallons daily.		
40 acres of land	$200,000	
Receiving basin	54,000	
Filters	472,000	
Piping and connections	61,000	
Total		$787,000
Cambria site; Spring Garden pumping station, 30 acres of filters; capacity, average, 60,000,000; maximum, 90,000,000 gallons daily.		
Land now owned by the city.		
Receiving basin	$103,000	
Filters	1,030,000	
Piping and connections	445,000	
Total		$1,578,000
Frankford pumping station, 10 acres of filters; capacity, average, 20,000,000; maximum, 30,000,000 gallons daily.		
20 acres of land	$20,000	
Centrifugal pumps and accessories for lifting water from river to filters	55,000	
Filters	330,000	
Piping and connections	4,000	
Total		$409,000
Total cost of filters with a maximum capacity of 195,000,000 gallons daily in connection with existing pumping stations		$3,391,000

In case the city is unwilling to bring itself to a reasonable use of water, and insists on wasting water as at present, the cost will be increased in proportion to the quantity of water required. The land provided for, however, at Roxborough and Queen Lane is sufficient for the construction of filters with twice the areas of those estimated for, and this item would not, therefore, increase with additional filters on those sites.

The cost of the operation of the filters may be approximately estimated upon a very liberal basis at $3.50 per 1,000,000 gallons of water filtered, or, for the quantity of water estimated for, $166,075 annually. This capitalization at 5 per cent. amounts to $3,321,500.

When additional quantities of water are required the capacity of filters at the Belmont, Roxborough and Queen Lane stations can be increased in connection with those now estimated for, the areas of land being ample for the requirements for a long period of years. The capacity of the filters on the site of the proposed Cambria reservoir, filtering water from the Spring Garden pumping station, can also be increased if desired, although the area of land available is apparently limited, and might not be sufficient for the ultimate requirements. It will, however, be better in many ways to get additional water for the district from the Delaware, instead of from the Schuylkill. Additional filters can be placed on the Delaware at any point selected as most suitable for this purpose.

As mentioned earlier in this report, investigations have not been made to determine the most advantageous point for taking the Delaware water. In case the water should be taken at a point immediately below Torresdale, works for an additional supply of 100,000,000 gallons daily would cost about $3,000,000, of which $1,100,000 would be required for filters, as much more for force mains from the filters to Market Street, connecting at various points with the pipes leading the water to all parts of the city, and $800,000 would be required for pumps, land and various accessories.

The total cost of works for securing water in this way amounts to about $30,000 for every 1,000,000 gallons daily

capacity secured, and the works would be of such a nature that any considerable part of them could be installed at nearly the same proportionate cost, and the capacity could be increased as required at the same rate. I do not consider that such a large additional quantity of water will be required in the near future, but the estimate is included that you may know the expense which will be involved in case the city insist upon having so large a quantity of water as 300,000,000 gallons or more per day.

CONCLUSIONS.

The city of Philadelphia is now using water in a most wasteful and extravagant manner, and immediate measures should be taken to check such waste, and to reduce the consumption to a reasonable amount.

It is possible to construct sand filters similar to those in use at London, Hamburg and many other European cities, in connection with the existing pumping stations, of sufficient capacity to furnish water for all reasonable requirements, for the present population, and for that which may be expected in the near future.

When larger quantities of water are required, it will be possible to secure them from the Delaware River by means of filtration, and to use the water so obtained in connection with that from the present pumping stations. The quantity of water which can be secured in this way is practically unlimited, at least 1,000,000,000 gallons being available.

The cost of installing filters with all necessary accessories to filter an average of 100 gallons of water per day for every inhabitant in the city, and with a maximum capacity of 150 gallons per inhabitant per day, amounting to 195,000,000 gallons daily in all, may be approximately estimated at $3,400,000.

85 Water Street, Boston, Mass.,
September 1, 1896.

ELECTRICAL SECTION.

Stated Meeting, Tuesday, September 22, 1896.

MR. CLAYTON W. PIKE, President, in the chair.

ON THE JACQUES CARBON BATTERY, AND ON A THERMO-TROPIC BATTERY.

BY C. J. REED.

[At the meeting of the Electrical Section of the Franklin Institute, held September 16th, Mr. C. J. Reed repeated, by request, some experiments on various modifications of the Jacques battery, and also exhibited several forms of his "thermo-tropic" battery.

He described the thermo-tropic battery or junction as a variety of thermo-electric junction, consisting of two pieces of metal separated by an intervening film of metallic salt, oxide or hydrate.

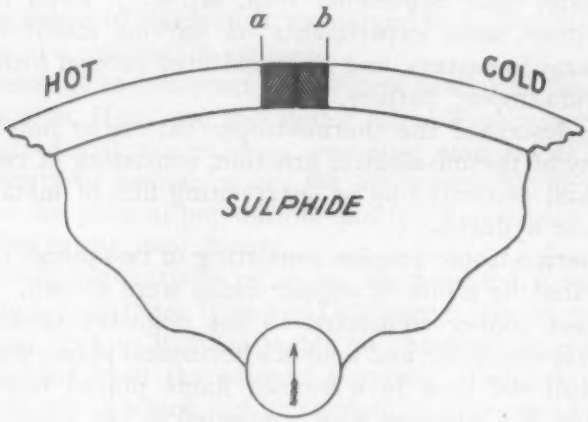
Thermo-tropic couples consisting of two pieces of copper separated by a film of copper oxide were shown. A piece of sheet copper connected to the negative terminal of a Weston voltmeter, and held in a horizontal plane, was heated to a dull red heat by a Bunsen flame placed beneath. A piece of No. 7 copper wire connected to the positive terminal of the voltmeter was then brought in contact with the upper surface of the hot sheet of copper. A deflection indicating nearly 0·4 volt was obtained.]

DISCUSSION.

ELIHU THOMSON.—My observations and experiments with cells such as that invented by Dr. Jacques have tended to show that the air introduced has for its function the formation of a film of oxide on the iron-containing cell wall, and that during the action of the cell this oxide film is continually reduced to metal, possibly by nascent sodium from the sodium hydrate.

It is well known that carbon in the presence of hot melted sodium hydrate tends to reduce it, and that at a sufficiently elevated temperature the reduction actually takes place and sodium is liberated. At lower temperatures there may be formed a polarized molecular chain, which, by oxidation of carbon, sets free the sodium ions at the other pole so as to reduce the iron oxide continually forming from the oxygen of the air introduced.

Turning now to the experiments of Mr. C. J. Reed, and especially that with the copper wires with a layer of copper oxide between, it appears to me that the effects obtained



are essentially thermo-electric, the film of oxide representing an exceedingly short element, the junction of which with the hot copper on one side is so much higher in temperature than the junction of the film on the other side as to give a considerable potential. There may be facts which would negative or modify this view of the action, but as yet I am not aware of any. Suppose the oxide to be replaced by sulphide and thickened somewhat. We would then have the arrangement in the above figure, where *a* would be a hot copper and copper sulphide junction, and *b*, a cooler sulphide and copper junction, with the result of the production of E.M.F.

Many years ago, in Philadelphia, while experimenting with thermo-junctions, I noticed effects similar to those brought out by Mr. Reed, *i. e.*, on touching a cold piece of zinc with a copper wire that had been scaled by heating in the air, and which was still hot, a quite strong deflection was obtained with a galvanometer in the circuit connecting the two metals, and that this deflection exceeded by several times that obtained when the metals were used as a simple junction heated in the usual way.

It appears to me that what Mr. Reed has done is to very greatly reduce the length of the badly-conducting element of the couple, namely the oxide or other metallic compound. It is too early to predict the practical value of the arrangement, but it is sincerely to be hoped that the thermo-electric principle of generation of current may possibly in this way reach a practical development not otherwise possible.

I shall certainly be interested to learn of the further work of Mr. Reed in this very fascinating study. I regret that distance prevents my being present at the meeting of the Electrical Section.

MR. REED.—The fact stated by Prof. Thomson, that a film of ferric oxide on the cell wall of the Jacques battery undergoes continual reduction to metallic iron, is very instructive. It is quite certain that, whatever the nature or origin of the current may be, whether it be galvanic or thermo-electric, it must, by electrolytic action, cause at the cell wall a reduction of some constituent of the electrolyte. If the electrolyte consists of pure sodium hydrate, the only possible reduction products are hydrogen and sodium, either of which, at the temperature employed, reduces all known oxides of iron to the metallic state. I think, however, there is a more probable explanation of the reduction of the iron.

It is well known that alkaline hydrates, at the temperature employed in the Jacques battery, oxidize iron with formation of alkaline ferrates. The electrolyte, therefore, instead of being a pure alkaline hydrate, is undoubtedly a mixture of alkaline hydrate and alkaline ferrate, from which the iron would be reduced directly by the current more easily than either hydrogen or the alkali metal. It seems

to me more probable, therefore, that there is original reduction of the iron rather than of sodium, since sodium cannot be reduced under any conditions except such as would first and more easily reduce iron. This would be particularly true if the reduction were not electrolytic, but by contact with heated carbon, as Prof. Thomson assumes.

The facts stated by Prof. Thomson suggest that a more suitable electrolyte than alkaline hydrates and ferrates might be found in such salts as the alkaline arsenates, arsenites, bismuthates, plumbites, zincates, chromates and manganates, formed by fusing the oxides of arsenic, bismuth, lead, zinc, chromium and manganese with the alkaline hydrates. All these salts, except the plumbites and zincates, are capable of reduction by forming a lower oxide and without reducing a metal to the free state.

I agree with Prof. Thomson that the thermo-tropic junction is only a species of thermo-electric junction in which one metal is replaced by an electrolyte. At one time I thought the development of E.M.F. might be due to the flow of heat across the film of the electrolyte from one piece of metal to the other; but it involves less theory to suppose that the fused and solid electrolytes have an enormous thermo-electric power, and that the cold wire acts merely as a conductor to complete the circuit.

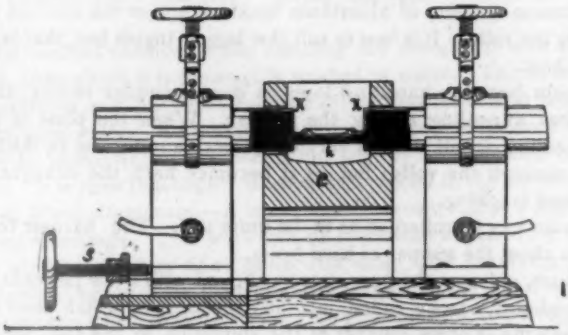
Without wishing to discourage the hope that a practical solution of the coal problem may be reached by thermo-electric batteries containing electrolytes of high thermo-electric power, I believe that the most serious defect of all galvanic batteries will also be found lurking in all thermo-electric batteries containing electrolytes. I refer to the fact that in all such batteries the evolution of electrical energy depends upon and is commensurate with the mechanical destruction of the apparatus itself, the cost of renewing which is always much greater than the entire cost of the fuel itself.

NOTES AND COMMENTS.*

AN ELECTRIC ASSAY FURNACE FOR RICHARDS' METHOD OF SEPARATING GOLD AND SILVER BY VOLATILIZATION.

In the discussion of Dr. Richards' paper on the separation of silver and gold by volatilization, it was suggested that it would be advantageous in this operation to employ electric heat, for the reason that in a properly constructed furnace of this type, the temperature could be much more readily controlled than by the use of the blowpipe flame.

Commenting on this suggestion, Dr. W. Borchers, in a recent impression of the *Zeitschrift für Elektrochemie*, describes an electric furnace devised and used by him for metallurgical work on the laboratory scale, and which he recommends as being well adapted for the special purpose above named.



Referring to the cut, *K* and *K* are two carbon electrodes about 40 millimeters in diameter, between which is placed a small carbon bar *k*, 6 to 8 millimeters thick. This bar is hollowed out to receive the test piece, and if it be desired to avoid bringing it in contact with carbon, the hollowed portion may be given a lining of magnesia, or of some other suitable refractory material.

This arrangement of parts is, as shown by the cut, enclosed within a suitable crucible *C*. To avoid the rapid burning out of the carbon bar, a few fragments of charcoal are thrown into the crucible. The manner of holding the bar *k* in position, and of introducing the current is so obvious as to need no special description. The electrode support on the left is made adjustable, so that the carbon cradle for the test piece may be firmly held in place by operating the hand-screw *S*.

According to Borchers, a current density of 5 ampères per square millimeter of section of *k* at the recessed part, will, be sufficient for the purpose of the assay. W.

* From the Secretary's monthly reports.

PRACTICAL HINTS ON WORKING ALUMINUM.

The following practical hints on manipulating aluminum for various purposes are abstracted from various communications which have appeared in the *Aluminum World:*

In *annealing aluminum* an even heat should be maintained in the muffle, and the metal, on being withdrawn, should be allowed to cool slowly. The temperature should be such that a piece of iron or steel placed in the muffle in the dark will show a red heat; for annealing thin sheet, a much lower temperature will suffice. The best test as to when the aluminum has come to the proper heat is to observe whether the metal will char the end of a pine stick, which should leave a black mark behind it as it is drawn over the plate. The metal should be at this temperature throughout, and not only on the surface.

For thin sheet and wire, it is sufficient to draw the pieces slowly over a fire and observe, by bending the metal, whether it has become soft enough.

The extreme ductility of aluminum makes it one of the readiest metals to work under the rolls. It is best to roll the larger ingots hot, that is, at a low annealing heat.

Aluminum becomes hard and loses its ductility under rolling, and therefore requires annealing during the process. When the plate is soft from recent annealing, it will stand a very considerable reduction in thickness on each pass through the rolls; but as it becomes hard, the draught must be light to avoid cracking.

Aluminum can be rolled so as to be quite stiff. The hardest rolled aluminum has about the temper of hard brass.

Aluminum, either in the pure state or alloyed with a few per cent. of hardening ingredients, can be rolled into any sections in which steel is rolled. In estimating the relative weights of the aluminum to the steel sections, the fact should be borne in mind that the sections in steel weigh 490 pounds to the cubic foot, and that the corresponding aluminum sections will weigh 168 pounds to the cubic foot, the ratio being 2·847 : 1.

Cast aluminum can be very much improved in rigidity and tensile strength if afterwards subjected to the drop-forging process. For special light-running machinery, drop-forgings of the nickel-aluminum casting metal produced by the Pittsburgh Reduction Company are particularly well adapted.

Plating Aluminum.—A process for cleaning the surface of aluminum, either for soldering or plating, is to dip the sheets into nitric acid diluted with three times its bulk of hot water, and which has had added to it just enough hydrofluoric acid to cause it to act on the surface of the metal, this action being denoted by the evolution of gas bubbles. The solution can be kept either in a wooden or lead-lined tank, and the amount of hydrofluoric acid added need be only small, say less than 5, or, at most, 10 per cent. of the volume of the solution. The hydrofluoric acid of commerce, sold in leaden jugs, and costing about 5 cents per pound, will answer the purpose.

The aluminum, after being cleaned in this dilute nitric and hydrofluoric acid solution, is again dipped into hot water for rinsing and dried in hot saw-

dust; it is then cleaned, so that either solder or plating solutions can be readily applied.

Aluminum which has been specially cleaned by any of the means suggested in the preceding paragraph, can be readily plated with copper in the way that such platings are usually applied.

Upon the copper plating, which can be put on in a very adhesive coating of any desired thickness, either gold, silver, nickel or other plating solutions can be applied. In some cases, aluminum can be advantageously plated with other metals directly, without first plating with copper.

Aluminum is now sold at a price per pound nearly equal to that of nickel, and not largely in excess of that of German-silver; volume for volume, it is much cheaper than German-silver, and for replacing German-silver or Britannia metal as a base in silver-plated vessels, its power of retaining heat, and its lightness, together with its much cheaper price, give it such advantages as will cause its extensive use.

After being plated with silver or copper, the article may be treated by the sulphide process for "oxidizing," giving the same results as "oxidized silver."

Another method consists in first cleaning the aluminum with an alkaline carbonate, after which it is thoroughly washed in water. This is followed by an immersion in a 5 per cent. solution of hydrochloric acid and another washing in pure water. A preliminary deposit of copper is then placed on the article by immersing it in a weak, but slightly acid, solution of sulphate of copper. It is then thoroughly washed and placed in the electrolytic bath.

How to Work Aluminum.—A brass scratch-brush, run at a high speed, is used on sand castings. This work can be somewhat lessened by first taking a leather wheel and a very fine Connecticut sand, and revolving this wheel at a high rate of speed on a polishing lathe, feeding the sand at the same time between the wheel and the casting, so that the skin and irregularities in the surface are removed, and then putting the casting on a buffing-wheel, or scratch-brushing it; in this way a variety of different effects can be produced. A fine brass scratch-brush gives a most beautiful finish to sheet metal or to articles manufactured from the sheet. By this means a frosted appearance is given to the metal, which effect, in many cases, is equal to that given by a high polish.

An effect similar to the scratch-brush finish can be given by sand-blasting. The effect of first sand-blasting and then scratch-brushing sheets gives a finish with very much less labor than with the scratch-brush alone.

Another very excellent frosted effect is secured by first sand-blasting and then treating as hereinafter described.

A very pretty mottled effect is secured on aluminum goods by first polishing them, and then holding them against a soft pine wheel run at a high rate of speed on a lathe, and, by careful manipulation, quite regular forms can be obtained.

This can be varied by first scratch-brushing or sand-blasting, and then holding it against a wheel as above described.

The same effect to a certain extent is given to aluminum by sand-blasting,

and aluminum which has been sand-blasted receives a grain which will allow of printing on the surface of the sheet with the best results, and aluminum sheets thus prepared are coming very largely into use for photo-lithographic purposes.

The surface in such cases is first sand-blasted in order that it shall take and retain the ink, and produce very clear and sharp outlines when printed from.

The faces for cyclometer dials, watch dials and similar articles, are generally sand-blasted before they are printed upon, which gives a very fine white background.

For dipping and frosting, remove the grease and dirt from the plates by dipping in benzine. To whiten the metal, giving a handsome frosted surface, the sheet should be first dipped in a strong solution of caustic soda or potash; then in a solution of undiluted nitric acid; then washed thoroughly in water and dried as usual in hot sawdust.

For burnishing use a bloodstone or steel burnisher. For hand burnishing, use either a mixture of melted vaseline and kerosene oil, or a solution composed of two tablespoonfuls of ground borax dissolved in about a quart of hot water, with a few drops of ammonia added.

Castings are polished by the use of a solid felt wheel, or a muslin wheel, as the nature of the work requires. In either case the wheel should be coated with emery of about No. 100 fineness, the emery being applied in the usual way with glue.

For "cutting down" sheets, use a muslin wheel with tripoli. For putting on a fine finish, or "coloring up" either castings or sheets, use a canton flannel buff, with snow-flake oil, or some other good coloring rouge.

If a particularly fine surface is desired in either castings or sheets, it is well to use, after polishing the castings, or after "cutting down," in the case of sheets, a sheepskin buff with pumice stone and oil.

The best lubricant to use on aluminum when being turned in the lathe is either petroleum or water, and in the press, when the metal is being drawn or stamped, vaseline.

THE NEED FOR AN IMPROVED TROLLEY.

The *Electrical World* says, editorially, that it is generally recognized that the trolley is a weak point in an electric railway equipment, yet no determined effort has been made to meet this deficiency. This weakness consists in the absence of that most important requisite in a device of this character—reliability. The standard trolley, now almost universally used, is prone to jump the trolley wire at any moment, and render the car helpless for the time being. This happens so often that its occurrence has of late almost ceased to excite any apprehension or comment. It is frequently the case that needed and imperative reforms are neglected through sheer indifference, and not until an unavoidable accident happens is any real effort put forth to remove the cause. Any one at all observant cannot fail to discern the possible danger brought about by the trolley jumping the wire when the car is

upon a grade, or of a car getting stalled from like cause while crossing a railway track. Two serious accidents resulting from these very circumstances have occurred in the immediate vicinity of New York within a short time, proving that these fears are well founded. A few weeks ago a car on a Brooklyn road ran backward down a hill by reason of the trolley jumping the wire, and only recently a car slipped its trolley connection while crossing a railway track, and in this helpless condition was struck by a train. Apart from the question of blame for these accidents, they demonstrate most emphatically the danger to which many lives are daily exposed in cities and suburbs through the uncertainty of the trolley staying where it belongs. If an improvement in electric railway equipments was ever needed it is certainly presented here, and it is assuring that one concern has produced a trolley device that is designed, among other things, to avoid just such accidents. The solution is not a question involving great engineering skill, but simply a change from existing practice.

RULES OF THE ROAD AT SEA.

At its last session Congress finally passed, and the President thereupon approved, the bill making amendments to the proposed new rules of the road at sea. It was hoped that the new rules could be proclaimed this summer, but this is now found to be impossible.

It is the intention of the State Department to communicate with all foreign governments, asking that they agree upon some date for the rules to go into effect. It is expected that about March 1, 1897, will be the date selected. When it is agreed upon the President will issue a proclamation. The law, as it goes on the statute books, is as follows:

Article 15. All signals prescribed by this article for vessels under way shall be given—

"(1) By 'steam vessels' on the whistle or siren.

"(2) By 'sailing vessels' and 'vessels towed,' on the fog-horn.

"The words 'prolonged blast,' used in this article, shall mean a blast of from four to six seconds' duration.

"A steam vessel shall be provided with an efficient whistle or siren, sounded by steam or by some substitute for steam, so placed that the sound may not be intercepted by any obstruction, and with an efficient fog-horn, to be sounded by mechanical means, and also with an efficient bell. (In all cases where the rules require a bell to be used, a drum may be substituted on board Turkish vessels, or a gong where such articles are used on board small sea-going vessels.) A sailing vessel of 20 tons gross tonnage, or upward, shall be provided with a similar fog-horn and bell.

"In fog, mist, falling snow or heavy rainstorms, whether by day or by night, the signals described in this article shall be used as follows, namely:

"(A) A steam vessel having way upon her shall sound, at intervals of not more than two minutes, a prolonged blast.

"(B) A steam vessel under way, but stopped, and having no way upon

her, shall sound, at intervals of not more than two minutes, two prolonged blasts, with an interval of about one second between.

"(C) A sailing vessel under way shall sound, at intervals of not more than one minute, when on the starboard tack, one blast; when on the port tack, two blasts in succession, and when with the wind abaft the beam, three blasts in succession.

"(D) A vessel when at anchor shall, at intervals of not more than one minute, ring the bell rapidly for about five seconds.

"(E) A vessel when towed, a vessel employed in laying or in picking up a telegraph cable, and a vessel under way which is unable to get out of the way of an approaching vessel through being not under command, or unable to manœuver as required by the rules, shall, instead of the signals prescribed in subdivisions (A) and (C) of this article, at intervals of not more than two minutes, sound three blasts in succession, namely: One prolonged blast, followed by two short blasts. A vessel towed may give this signal, and she shall not give any other.

"Sailing vessels, and boats of less than 20 tons gross tonnage, shall not be obliged to give the above-mentioned signals; but if they do not, they shall make some other efficient sound signals at intervals of not more than one minute.

"Section 2. That said act of August 19, 1890, as amended, shall take effect at a subsequent time, to be fixed by the President by proclamation issued for that purpose."—*Scientific American.*

ELECTRICITY DIRECT FROM CARBON.

The following paper was presented by Dr. Alfred Coehn to the *Electrotechnischer Verein*, of Berlin, and is reproduced from an English translation of the *Engineering and Mining Journal*:

The problem of the direct production of electricity from carbon would find its simplest solution if we could succeed in dissolving carbon in a fluid, just as we do metals. This question is formulated thus by the theory of electrolysis: Can carbon form ions?

In attempting to find an answer to this question, I started from an observation made by Bartoli and Papasogli, that when dilute sulphuric acid was electrolysed between carbon electrodes, the carbon anode takes part in the electrolytic processes, in such a way that, besides oxygen, both carbonic oxide and carbonic acid make their appearance at the anode. I began my experiments by varying the important factors, viz.: concentration, temperature and current density, in order to discover whether it was possible to obtain the products of combustion without admixture of oxygen on the anode. I have not succeeded in obtaining carbonic acid or carbonic oxide alone, but a mixture of the two, containing only 1 per cent. of oxygen. In this mixture about 70 per cent. was carbonic acid and 30 per cent. carbonic oxide.

In these experiments it was observed that at low temperatures a disin-

tegration of the carbon anode took place, small particles of carbon being seen suspended in the acid. At higher temperatures, on the contrary, no such disintegration of the carbon took place, but a distinct coloration of the acid was produced, at first yellow, then later dark red and red-brown. If this is a solution of the carbon brought about by the current, the carbon is presumably contained in it, in the form of ions, *i. e.*, in a form capable of being influenced by the directing power of the current. Such a solution must be capable of giving up carbon to the cathode, since carbon does not decompose water. (A series of platinum plates, coated with carbon, was shown, and a dish, such as is used by Classen for quantitative electrolytic analysis, was shown coated inside with a dense layer of carbon.) The solution and precipitation could readily be obtained with different kinds of coal as anode. Ordinary coal, ground smooth, and arc lamp carbons, were found specially suitable; the experiment also succeeded with coke.

That the precipitate was really carbon, and not metal derived from impurities in the coal, was shown by treatment with acids. It was not attacked by hydrochloric acid; in hot nitric acid traces were dissolved—as in the colorimetric test for carbon in steel. In the flame, even the densest precipitates completely disappeared immediately. Finally, a direct proof was obtained by oxidizing the precipitated carbon by chromic acid, and absorbing the resulting carbonic acid in alkali. A number of analyses were made, and these always showed, in addition to carbon, a little hydrogen. The residue—reckoned as oxygen—was sufficient to convert the hydrogen found into water. Either, therefore, in addition to the carbon, a solid conducting carbohydrate was separated, or some kind of crystalline water which adhered strongly to the carbon was produced. The presence of water in the precipitate is indicated by its behavior with concentrated sulphuric acid. If the acid is dropped on the precipitate it is immediately loosened and blackened, reminding one of the behavior of sulphuric acid with a carbohydrate.

It was now of interest to attempt to construct an element whose soluble electrode consisted of carbon. The only question now was to place a more electro-negative element opposite the carbon. The peroxides stand nearer even than carbon to the negative end of the potential series. Lead peroxide was used in the practical form of a charged accumulator plate. If this be placed opposite a carbon in sulphuric acid of the proper concentration, temperature, etc., an element is formed of which carbon is the soluble electrode. The element supplies a strong and constant current. Through an external resistance of 100 ohms it shows an E.M.F. of 1·93 volts.

There arises here the question whether any share in the production of the current is due to the reaction on the carbon, and if so, what share? Platinum also, when placed opposite a peroxide plate under the same conditions, shows a current in the same direction as the carbon. But it never comes to a visible development of oxygen; as soon as the platinum is charged with oxygen the current becomes exceedingly small. If the carbon were an insoluble electrode it would behave in the same way; but this

is not the case. The current lasts till the accumulator plate is discharged. A second charged peroxide plate may then be substituted, and the current is again produced as strong as before.

The results of my investigation may be summarized as follows:

(1) It is possible by electrolysis to produce a solution of carbon.

(2) From such a solution carbon may be separated as a kathion.

(3) An element may be formed of which carbon is the soluble electrode.

NEW USE FOR OLD HORSE CARS.

We learn from the *Electrical World* that a novel but very sensible use is made of old horse cars in Connecticut. When the trolley system was introduced in the various cities in that State, the problem as to what should be done with the old horse cars remained unsolved, until some enterprising genius suggested using them for summer cottages, hunters' camps, lodges, etc. The public readily fell in with the idea, with the result that all of 600 old cars that went into disuse are now being utilized for these novel purposes. It is stated that all along the Long Island coast, from Watch Hill to Larchmont, these cars may be seen perched up on top of some breezy bluff on the sandy shore, or in some quiet, shaded nook, affording temporary habitation for families, fishermen, hunters, etc. The demand for old horse cars has greatly increased in consequence of this new use. One woman recently asked the station agent at New London for his lowest prices for passenger cars, also a list of the various styles. A Norwich party has arranged four cars in the form of a hollow square, and erected a canvas awning in the square. One of the cars is used as the kitchen and the others as sleeping-rooms, dining-room, parlor, etc. One gentleman has five cars on Block Island, which he has placed end to end, like a train. The supply of old cars in this one State has thus suddenly become exhausted.

PROCESSES FOR THE NICKEL-PLATING OF WOOD.

The nickel-plating of wood for various decorative uses, such as canes, umbrella handles, etc., is extensively practiced both in Europe and this country. The *Electrical World* gives the following formula for the purpose:

The articles which are to be plated with nickel must first be coated with metal. In the process which is most commonly employed three solutions are made use of, namely: (*a*) 1½ grams of caoutchouc slicings are dissolved in 10 grams of carbon bisulphide, and 4 grams of melted wax are poured into the solution; a mixture consisting of 5 grams phosphorus in 60 grams of carbon bisulphide, with 5 grams of turpentine and 4 grams of powdered asphalt, is then added and the whole shaken. (*b*) 2 grams of silver nitrate are dissolved in 600 grams of water. (*c*) 10 grams of chloride of gold are dissolved in 600 grams of water. The conducting wires are attached to the article, which, after being immersed in the first solution, is allowed to dry. The second solution is poured over it, and it is kept suspended until the sur-

face has a dark luster, when it is rinsed with water and treated in a similar manner with the third solution. The surface has now a yellowish sheen, and the wood is sufficiently prepared for electrolytic deposition. Langbein's dry process consists in quickly pouring over the article a collodion solution of potassium iodide, diluted with an equal volume of ether-alcohol; when the layer is just about to set, the wood is laid in a weak solution of silver nitrate, light being excluded. As soon as a yellow color appears, the wood is rinsed, exposed to sunlight and covered with copper; it is then ready to be nickel-plated. The wood may also be treated with immersion in an ethereal solution of paraffin or wax, and when the ether has evaporated, fine graphite is powdered over them, or the wax is covered with bronze powder, and all unevenness of surface removed. When the articles are to be electrolytically coated with copper they are placed in a bath the composition of which varies with the current employed; generally, it consists of 30 liters of 18 per cent. copper sulphate solution, and 1½ liters of 66 per cent. sulphuric acid. When a sufficient amount of copper is deposited the articles are ground, polished and nickel-plated in a bath composed of 500 grams of ammonium-nickelous sulphate, 50 grams of ammonium sulphate, and 10 liters of distilled water. If the blue litmus paper be quickly reddened by this solution, the acidity is reduced to such a point by addition of ammonium chloride that the reddening is only slowly developed.

ROLLER SHIP LAUNCHED.

In the presence of numerous foreign engineers and a large crowd of onlookers, the so-called "roller steamer," the invention of M. Bazin, a well-known marine engineer, was launched August 19th, at the Cail dock-yards, at St. Denis, France. The vessel will traverse the Seine, cross the English Channel, and go to London.

The boat is a large, rectangular iron box, about 120 feet in length, 40 feet wide, and 5 feet high. It is mounted on six lenticular discs or rollers, 30 feet in diameter and sunk in the water 10 feet, while the lower floor of the box is at an equal distance from the level of the water. In the sides of the box is the machinery, which is of 750 horse-power. This sets in motion a screw and the rollers. In the upper part of the vessel, between the discs, which pierce the box and extend beyond it about 7 feet, are comfortable cabins. This strange-looking vessel has a displacement of 280 tons.

M. Bazin's first experiments were made with a small model, the rollers of which were moved by clockwork, the propeller being replaced by a weight, which was attached by a string passing over a pulley to the front of the boat. When the rollers were not working the miniature boat took twenty-two seconds to cross from one side of the large vessel in which it was placed to the other side. When they were working it took only eleven seconds. As the power necessary to keep the rollers at work is only one-quarter of the power that is required to keep the screw going, the mathematical result is that the speed of the vessel is doubled by an extra expenditure of power, which amounts to only one-quarter. But a vast increase of speed is not the only advantage claimed

for these rolling steamers. It is pointed out that when they shall be used the length of voyages will be diminished, the consumption of coal will be lessened, and, as a natural result, passengers and freight will be transported at far less expense than heretofore. Moreover, experts assert that the stability of the rolling boats will be far greater than that of the steam vessels at present in use. It is also asserted that the catastrophes at sea would practically cease by the use of rollers. In case of a collision or other accident, though some of the rollers might be damaged, some would almost certainly escape damage, and two would suffice to keep the vessel afloat and take her into port.

M. Bazin expects the boat to make from 45 to 50 kilometers an hour while crossing the channel. The theory of the inventor is that boats should roll over the water instead of cutting through it.

He has designed a large steamer on the same principle, which he estimates will make the voyage from Havre to New York in four days, but of course this speed is largely problematical.—*Scientific American.*

DAMASCUS GUN-BARRELS.

The making of barrels for sporting guns in the valley of the Vesdre, in the province of Liège, Belgium, is an interesting mechanical operation. These barrels are called "damascus," because the damascene appearance of the metal resembles that of the celebrated Damascus sword-blades, famous for their fine quality. The damascus gun-barrels herein described are made entirely by hand. The United States Consul at Liège has described this manufacture in one of his reports, from which we make the following abstract: The steel is imported from Westphalia; the iron is manufactured at Couvin. The factories receive their motive power from the River Vesdre. Some years ago, forges and workshops were entirely engaged in making iron barrels, and there were but few barrel-makers who produced tubes or barrels known as twist barrels, called by the French *canon tordu*, or *tors*, from *tordre*, to twist or contort. The ingot for the production of the curled damascus, which is the favorite design for fine guns, is composed of about thirty sheets of iron and steel, each having the thickness of 4 millimeters and a breadth of 120 millimeters, which form a square mass about 50 centimeters long, and are enveloped in a box of common thin sheet-iron or by small wires at each end. The package thus prepared is put into a furnace and welded together at the lowest possible temperature. Too great a heat destroys the metal and yields a burned damascus, showing a small, if any, design. Each barrel receives 150 welding heats while being forged. If one of these welding heats is unsuccessful, the barrel may be a failure, either by the alteration of the damascene appearance or by a trace of the smallest imperfection in welding. Swedish iron is not used in forming curled damascus; only refined iron of Belgium, which gives a greater contrasting hue to the steel, and can be welded at a lower heat. After the ingot is welded it is rolled into small square rods of 7 to 9 millimeters, according to the design of the damascus desired.

The rods are then drawn into ribbons by the smiths. The manipulation of these ribbons at high temperature is such that in a length of 1 meter, 200 twists are shown. Coke iron will not answer for this fine work, for which charcoal iron is used exclusively, though an inferior quality of damascus can be made from coke iron. The twisting increases in pitch toward the thinner part of the barrel, which is first formed by winding the ribbons on a mandrel, and welding the coils together at the edges. The barrels are then bored out, straightened, ground to the proper thickness and polished. The joining of the barrels for double-barreled guns is a process requiring great care, as the value of the gun largely depends upon the accuracy with which this part of the process is executed. Each barrel is proved by a shooting test at the manufactory before it is placed on sale. It is said that the annual production of these barrels is 300,000, and that they are exported chiefly to England and the United States.

BOOK NOTICES.

The Dynamo. How made and how used. By S. R. Bottone. Ninth edition, with additional matter and illustrations. New York: Macmillan & Co., 66 Fifth Avenue. (John Wanamaker, Philadelphia.) Price, 90 cents.

The favor with which this guide for the amateur in the construction and use of the dynamo has been received is tolerably good evidence of its usefulness. Books of this class fill a gap for which the scientific treatises afford no substitute, and, with fair accuracy of statement in what relates to essentials, have an educational value for a numerous class which it would be difficult to overestimate. Mr. Bottone's book is one of the best of its kind. For a future edition we would suggest to the publishers the desirability of better illustrations. In these days of cheap engraving, the reprinting of old and badly worn cuts and the use of crude sketches for originals is unwise, to say the least. W.

PUBLICATIONS RECEIVED.

[In sending books for notice in the *Journal*, publishers are requested, for the information of the reader, as well as for their own advantage, to give the price. This announcement by title will be followed, in most cases, by a review, which will appear at the earliest opportunity.]

Expanded Metal and its uses in fire-proof construction. Merritt & Co., Inc., engineers and contractors, Philadelphia.

Encyclopèdie scientifique des Aide-Mémoire, Paris: Gauthier-Villars et fils et Masson & Cie. 1896. Price, per volume, 2.50 to 3 francs.

The undermentioned additions to this series have appeared since our last notice:

Barillot, Ernest, Directeur technique d'usines de distillation de bois,

Membre de la Société chimique de Paris, Expert-Chimiste près les Tribunaux. *La distillation des bois.*

Hennebert, Lieutenant-Colonel du Génie, ancien Professeur à l'École militaire de Saint-Cyr, aux Écoles des Mines et des Ponts et Chaussées et à lÉcole supérieure de guerre. *Communications militaires.*

Ariès, E., Chef de bataillon du Génie. *Chaleur et Énergie.*

Hennebert, Lieutenant-Colonel du Génie, ancien Professeur à l'École militaire de Saint-Cyr, aux Écoles des Mines et des Ponts et Chaussées et à l'École supérieure de guerre. *Travaux de campagne.*

Franklin Institute.

[*Proceedings of the stated meeting, held Wednesday, October 21, 1896.*]

HALL OF THE FRANKLIN INSTITUTE,
PHILADELPHIA, October 21, 1896.

JOS. M. WILSON, President, in the chair.

Present, 104 members and visitors.

Addition to membership since last report, 1.

The Secretary reported the resignations of Messrs. C. O. Billberg, John E. Codman, Dr. C. B. Dudley and Fred. E. Ives, from the Committee on Science and the Arts.

An election resulted in the choice of Mr. Thomas Spencer for the unexpired term of Mr. Billberg, Mr. John Birkinbine for the unexpired term of Mr. Codman, Mr. Wm. C. Henderson for the unexpired term of Dr. Dudley, and Mr. Wm. R. Webster for the unexpired term of Mr. Ives.

Mr. Walter Atlee, civil engineer, of Philadelphia, read a paper "On the Improvement of the Channel of the Delaware River," setting forth what had already been accomplished, the plans at present being carried out and in contemplation for the future, for obtaining and maintaining an unobstructed deep-water channel in the river, from Philadelphia to the sea, capable of accommodating vessels of the largest draught. The speaker illustrated his paper with the aid of charts and lantern slides, exhibiting the depth and other physical characteristics of the river channel from Trenton to the sea.

The subject evoked a spirited discussion, which was participated in by Lieut.-Commander J. R. Selfridge, U. S. N., late in charge of the Branch Hydrographic Office, Philadelphia; Mr. L. Y. Schermerhorn, Mr. J. C. Trautwine, Jr., Prof. Lewis M. Haupt, Mr. Edwin F. Smith, Mr. Frank Rosengarten and others.

(Paper and discussion will be referred to the Committee on Publications.)

Adjourned.

WM. H. WAHL, *Secretary.*